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INVESTIGATION AND ASSESSMENT OF LIGHT-DUTY-VEHICLE EVAPORATIVE EMISSION SOURCES AND CONTROL

Exxon Research and Engineering Company

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Ann Arbor, Michigan 48105

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16. ABSTRACT

This study has assessed the effectiveness of current Evaporative Control Systems (ECS) and has shown the feasibility of various hardware approaches which control evaporative emissions to a very low level.

The performance of ECS's in current use was evaluated by using the Sealed Housing for Evaporative Determinations (SHED) procedure on twenty 1973-75 cars with representative control systems. The measured emissions ranged from 0.5 to 30.6 grams per test, and the twenty car average was 8.7 grams per test.

Hardware was then developed to improve ECS performance. Six production vehicles were modified to demonstrate the feasibility of improving current systems. These modifications were successful in lowering the evaporative emissions to less than 2.0 grams per test for each of the six modified vehicles. This six car group consisted of vehicles manufactured by General Motors, Ford, Chrysler, American Motors, Volvo and Mazda; and the costs of required hardware has been estimated at $2, $2, $6, $2, $2, and $25, respectively.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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I. INTRODUCTION

This report describes a study carried out by the Exxon Research and Engineering Company for the EPA to assess the effectiveness of light duty vehicle evaporative emission control systems.

Evaporative emissions from light duty vehicles have been controlled nationwide beginning with the 1971 model year vehicle. The emissions can be divided into two main categories: (1) carburetor emissions, and (2) fuel tank emissions. A control level has been set by EPA at 2.0 grams per test as measured by the "carbon trap" method. However, an improved measurement technique, the SHED method, has been developed recently. (SHED test, Sealed Housing for Evaporative Determinations, is SAE Recommended Practice J171a.) The new method has shown that the "carbon trap" method underestimates vehicular evaporative emissions. Because of this EPA has sought to conduct a study to determine the performance of in-use evaporative control systems with the more accurate SHED method. In addition, there is a considerable incentive to improve the performance of current evaporative control systems. This is because the exhaust hydrocarbon emissions have been reduced considerably in recent years and consequently the evaporative hydrocarbons represent an appreciable portion of total hydrocarbon emissions of a vehicle. This program, undertaken by Exxon Research and Engineering Company, is a study which addresses itself to the following facets of the vehicular evaporative loss problem:

1. A survey and analysis of evaporative control systems on current vehicles.

2. A study of the magnitude and source of evaporative emissions from current vehicles using the SHED measurement technique.

3. Modification of vehicles to demonstrate that performance of evaporative control systems can be improved.

4. The effect of severe operating conditions on evaporative losses from modified cars.

II. SUMMARY

In 1971, evaporative emission controls were imposed by EPA on light duty vehicles. This was to limit the loss of hydrocarbons evaporating from the fuel tank and carburetor of a vehicle. Recently, EPA determined that the test compliance method, known as the "carbon trap" method, underestimated evaporative emissions and a new test method has

been proposed by EPA[1]. The new test method, known as the SHED method, has shown that the evaporative emission controls in the field are less effective than originally estimated and in the case of some critical late model vehicles, evaporative emissions are of the same magnitude as the exhaust hydrocarbon emission.

To define and deal with the problem at hand, a program has been initiated at Exxon Research and Engineering Company with EPA sponsorship. This program has assessed the effectiveness of current Evaporative Control Systems (ECS) and has shown the feasibility of various hardware approaches which control evaporative emissions to a very low level. The performance of ECS's in current use was evaluated using a cross section of 1973-75 cars with representative control techniques. For this, the Sealed Housing Method for Evaporative Determinations (SHED), SAE J171a procedure was used. (This involves enclosing the vehicles in a shed and monitoring the hydrocarbon level in the shed.). The average evaporative loss for a 20 car group was 8.7 grams/SHED test. The lowest loss was 0.5 gram and the highest was 30.6 grams.

The results of this study indicate that the bulk of the evaporative losses occur during the hot soak phase of the SHED test, and the source of emissions is the carburetor bowl. Current ECS's appear effective in handling the diurnal loss from the fuel tank for most vehicles. The major source of loss was overflow from the air cleaner snorkel, indicating inadequate storage volume for carburetor hot soak vapors reaching the air cleaner. Hydrocarbons also escaped from poorly fitting seals and other leak sources. In some cases there was significant overflow from the carbon canister.

Hardware was developed to improve ECS performance. Six vehicles were modified to demonstrate the feasibility of improving current systems. The modifications involved: (1) the venting of the carburetor bowl to the canister to alleviate air cleaner overflow, (2) utilization of larger carbon beds, (3) adaptation of increased purge rates, and (4) sealing and capping of leak sources. These modifications were successful in lowering the evaporative emissions to 2.0 grams/SHED test or lower for each of the six modified vehicles. The costs of the hardware used to accomplish this has been estimated to vary from $2.00 to $25.00.

We have concluded from this work that it is feasible to markedly improve the performance of current evaporative control systems.

(1) 41FR2022

III. EVAPORATIVE CONTROL APPROACHES IN CURRENT USE

A. Sources of Evaporative Emissions

The evaporative emissions from a vehicle's fuel system can be divided into two main categories, (1) carburetor emissions and (2) fuel tank emissions. The evaporative emissions from the carburetor occur primarily because of fuel boiling in the carburetor bowl and, to a lesser extent, by diffusion across the hydrocarbon concentration gradients at the carburetor vents. The first process occurs during the "hot soak" period, that is when the heat from the engine is being dissipated to the surroundings after shutdown. This causes the temperature of the fuel in the carburetor bowl to rise over a period of about 30 minutes during which time fuel boils in the carburetor bowl. Beyond this point the carburetor slowly cools, the fuel stops boiling and the subsequent losses are primarily due to a diffusion process. Most of the carburetor losses occur during the rising temperature portion of the soak period.

The magnitude of carburetor hot soak losses is a function of the increase in bowl gasoline temperature during the hot soak, the volume of the bowl, and the fuel's volatility. Figure 1 is representative of operation on a gasoline with Reid Vapor Pressure (RVP) of 9 psi (62.1 kPa). Typical losses are in the neighborhood of 10-15 grams for a carburetor bowl gasoline temperature increase of 10 to 16°C (maximum temperature of 82 to 88°C). The band in Figure 1 spans the normal size range of carburetor bowl volumes from 50 cc (lower curve) to 100 cc. The range of carburetor bowl sizes found in the field is much larger than 50-100 cc's, and the fuel volatility can vary significantly, thus the range of possible carburetor hot soak losses is much larger.

Evaporative emissions from the fuel tank are primarily due to two concurrent processes which cause an increase in the temperature of the fuel in the tank. This rise in tank temperature can occur, (1) while the vehicle is standing still due to variation in the ambient temperature and the evaporation losses are then referred to as "diurnal losses", (2) while the vehicle is operating, due to heat transfer from the exhaust system to the fuel tank and the losses are then referred to as "running losses". The magnitude of fuel tank diurnal losses is shown in Figure 2. The abscissa is the maximum temperature reached during the diurnal, normally 27.7°C in evaporative emission testing. Again we are using the standard test fuel with a Reid Vapor Pressure of 9 psi (62.1 kPa). For the normal range of fuel tank volumes, using the prescribed 40% fuel fill, diurnal fuel tank losses vary from 10 to 25 grams or roughly 0.3 gram per litre of fuel tank capacity. Diurnal cycles to higher temperatures increase evaporative losses as shown.

FIGURE 1

CARBURETOR HOT SOAK EVAPORATIVE EMISSIONS
ARE STRONGLY AFFECTED BY MAXIMUM BOWL TEMPERATURE DURING SOAK

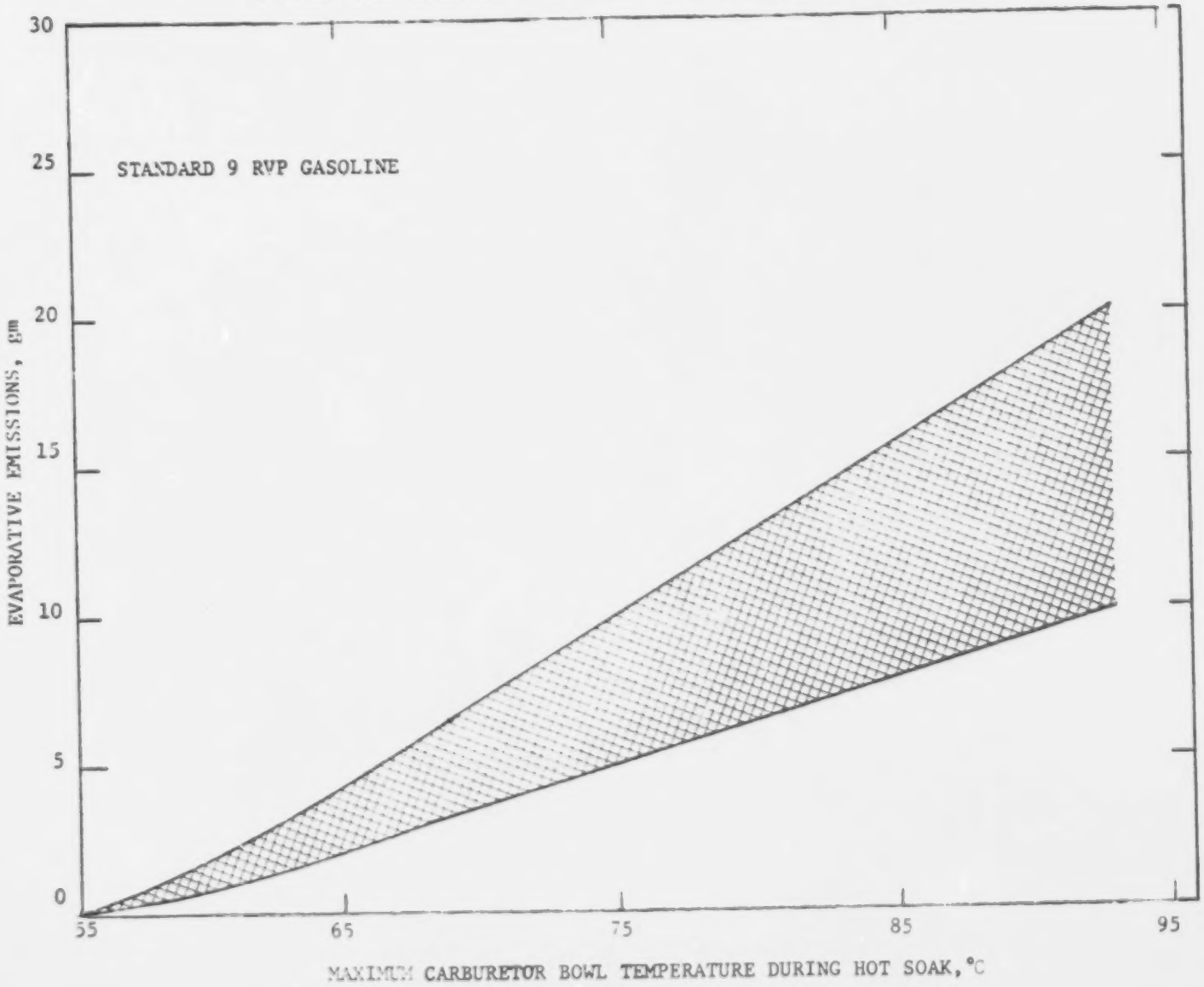
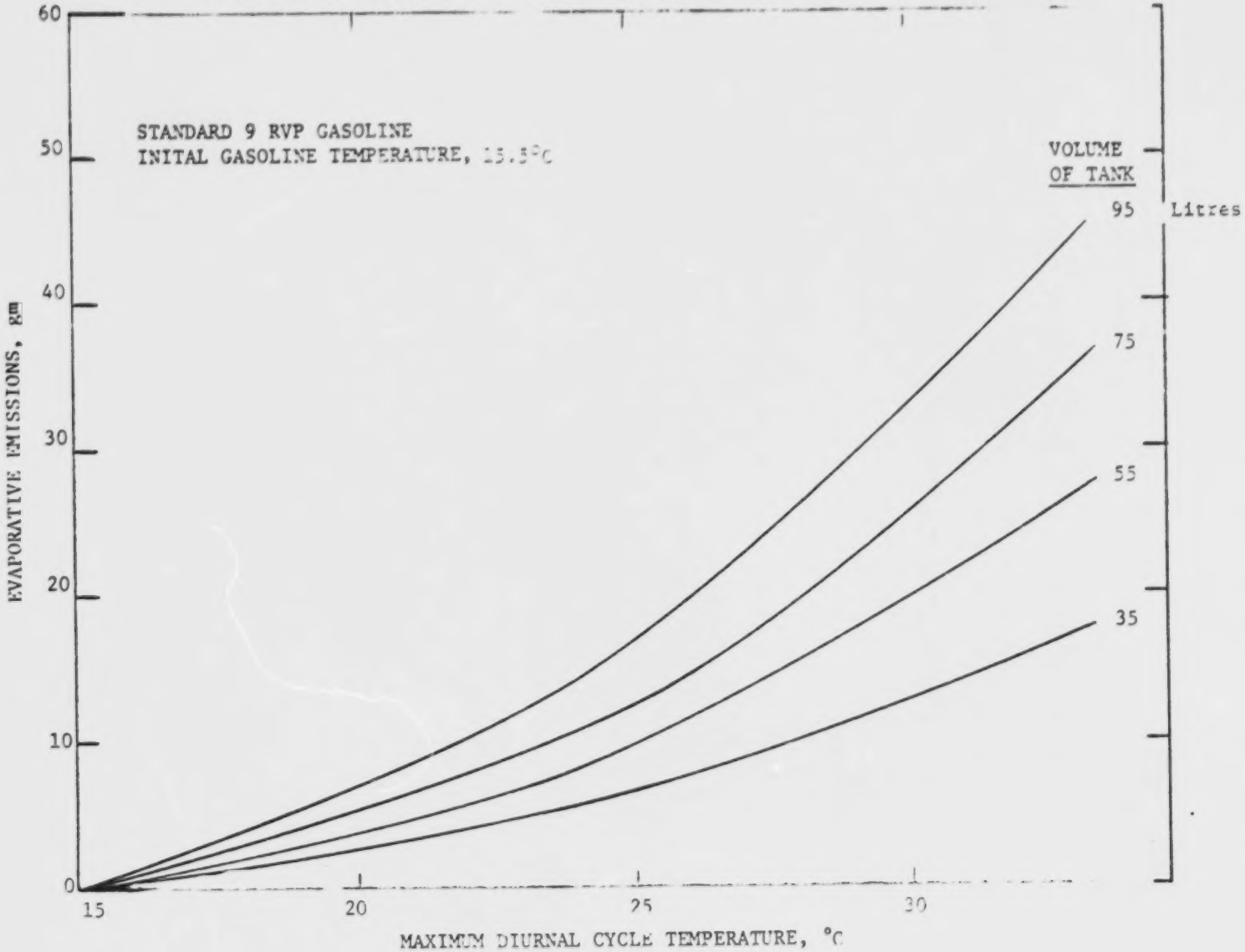


FIGURE 2

DIURNAL CYCLE EVAPORATIVE EMISSIONS
ARE STRONGLY AFFECTED BY AMBIENT TEMPERATURE RISE AND FUEL TANK VOLUME



Running losses from most ECS equipped vehicles are not significant. If fuel tanks have non-vented caps and are vented to the intake system, the vapors leaving the tank will be burned in the engine. Carburetor bowls are vented to the carburetor air intake, allowing vapors to be burned in the engine.

B. Current Automotive Practice for Control of Evaporative Emissions

In this section, the types of Evaporative Control Systems (ECS) used by the automotive industry are reviewed.

1. Carburetor Evaporative Emission Control

The two types of carburetor losses are running losses and hot soak losses. The running losses are controlled internally in the carburetor by venting from the carburetor bowl to the air intake of the carburetor via the balance tube (Figures 3 and 4), allowing carburetor running vapors to be burned in the engine. This is the case because the pressure in the intake is lower than that in the carburetor bowl when the vehicle is running.

To control hot soak losses during engine shutdown, two basic systems are used. The first is storage of the vapors in the induction system during shutdown followed by eventual consumption in the engine after start-up. The hydrocarbon vapors move from the bowl into the carburetor intake through the balance tube and then into the carburetor throat and air cleaner. Because hydrocarbons are denser than air, they displace the air. Figure 3 shows a system of this type.

The second control system for hot soak losses uses both the induction system and a charcoal canister to store vapors. A line from the bowl to the canister diverts a portion of the vapors to this alternate storage. This is illustrated in Figure 4. A carburetor vent valve opens the line to the canister at idle and while shut down. At other times, the line is closed. Vapors stored in the carbon canister are ultimately purged by a portion of engine combustion air which is drawn through the canister during operating modes.

2. Fuel Tank Evaporative Emission Control

Fuel tanks are designed as "closed" systems (non-vented fill caps) which are connected to a vapor storage system through a vapor-liquid separator. The vapor-liquid separator reduces system load by returning condensed and entrained liquid to the tank. Three types of vapor storage techniques are used: (1) charcoal canister, (2) engine crankcase, and (3) an auxiliary tank.

3. Charcoal Canisters

The majority of ECS's use a charcoal canister to store the hydrocarbon vapors emitted from the fuel tank. In most of these systems, the

FIGURE 3

EVAPORATIVE EMISSION CONTROL SYSTEM

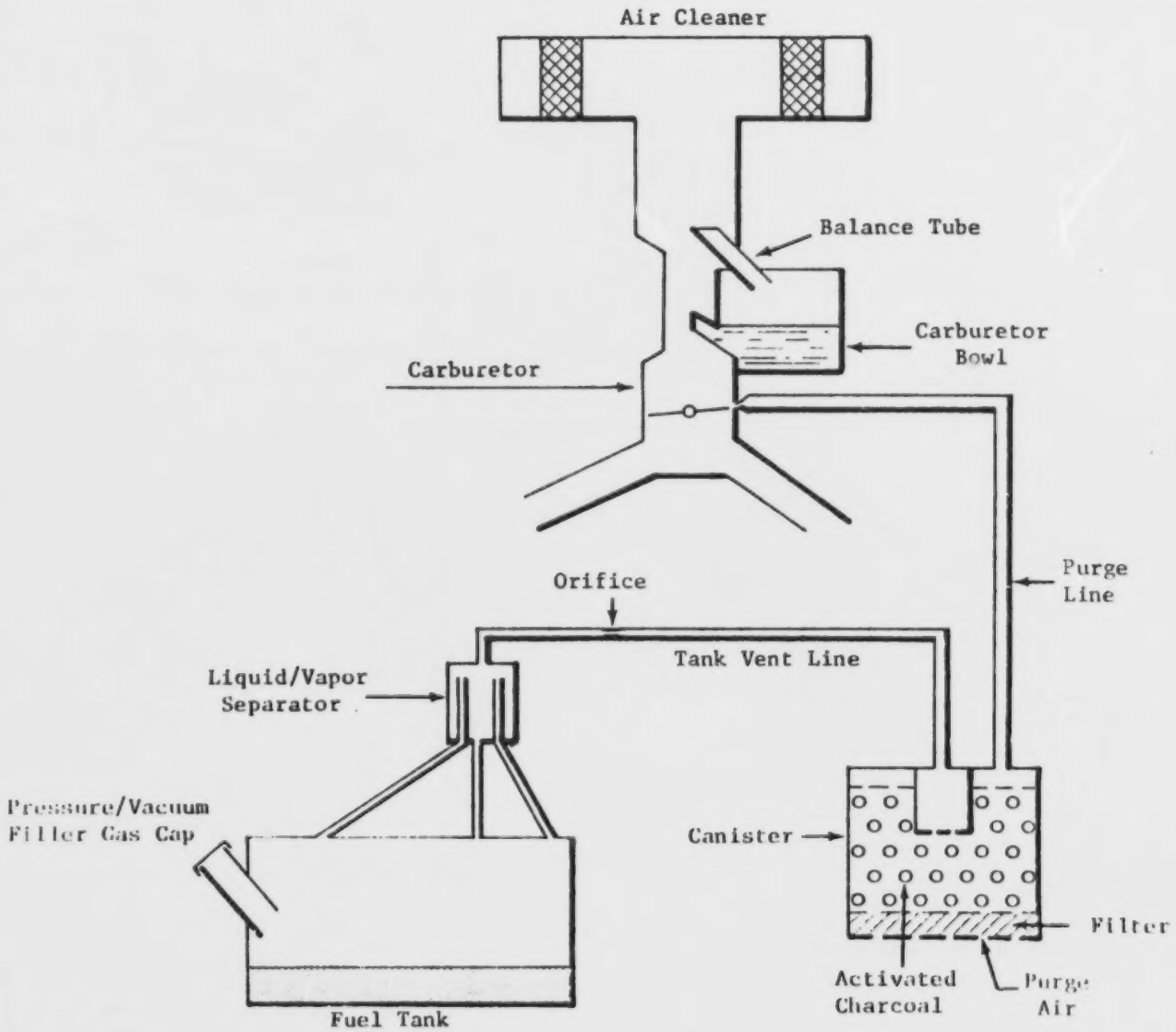
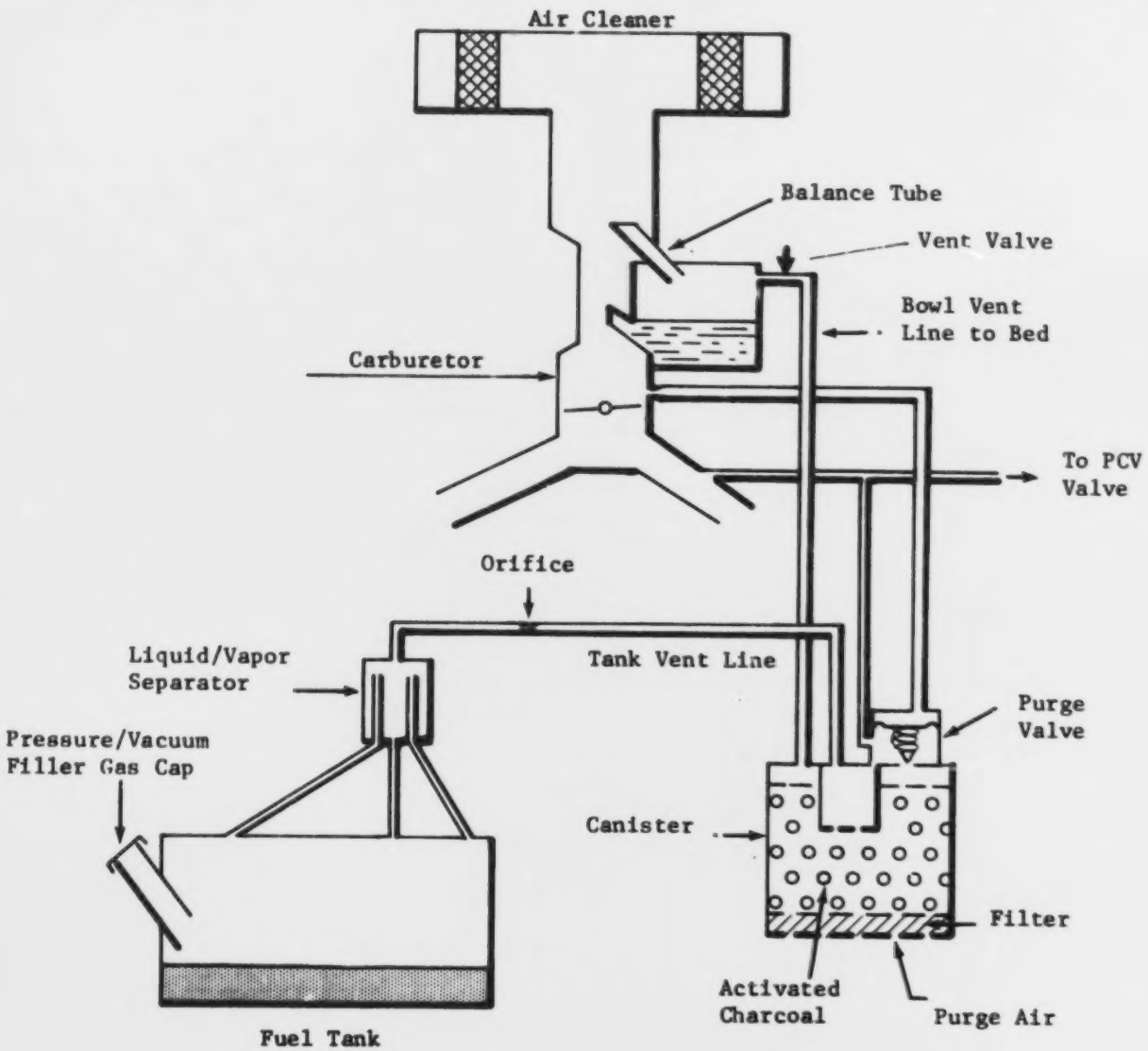


FIGURE 4

EVAPORATIVE EMISSION CONTROL SYSTEM



fuel tank vapors from both hot soak and running losses pass into the canister. A few systems, however, use a control valve which allows running loss vapors to bypass the charcoal bed and move directly to the engine.

The charcoal canister system functions via an adsorption-regeneration process. Hydrocarbon vapors are adsorbed on the surface of the activated carbon for storage purposes. Later the vapors are desorbed from the surface by passing a portion of engine combustion air through the charcoal bed. This regeneration, or purging process, is necessary to restore the capacity of the bed for further hydrocarbon storage.

There are several types of carbon canisters in use. They may be classified by the method of introducing purge air to the bed and by the technique for the handling of running vapors. In most cases, purge air enters the bed through the open bottom of the canister as illustrated in Figure 3. A replaceable filter is used to prevent dust contamination. A second type of canister in use has a sealed bottom with an air inlet on top. In some canisters, running vapors as well as hot soak emissions pass into the carbon bed. In others, a purge valve is used which allows running vapors to bypass the carbon bed. An example of this type of canister is illustrated in Figure 4.

4. Purge Systems

There are three general types of purge systems for regeneration of carbon beds. These systems can purge to: (1) the air cleaner, (2) the carburetor, and (3) the Positive Crankcase Ventilation valve (PCV). Units purging to the air cleaner generally utilize the pressure drop through the air cleaner and inlet system to draw purge air through the canister. One system utilizes the velocity of the air in the air cleaner snorkel to pull air through the carbon bed. Purging to the carburetor is the most popular technique. An example of this is shown in Figure 3. A port at the idle position is most often used so that at idle the purge rate will be very low but will increase as the throttle is opened. The third type of purge is to the PCV system. An example of this is shown in Figure 4. With this system, a purge valve is used which permits only tank running vapors to reach the engine at idle. As the throttle is opened from idle, engine vacuum opens the purge valve on the canister so that both tank running vapors and stored vapors in the bed are drawn into the engine via the purge air stream.

5. Summary of Techniques for Evaporative Emission Control

a. Carburetor Bowl Emissions To:
   - Induction system only
   - Both induction system and charcoal bed canister

b. Fuel Tank Emissions To:
   - Charcoal bed
   - Auxiliary Tank
   - Engine crankcase

c. Carbon Canister:
   - Open or closed bottom
   - All vapors enter the bed
   - Running vapors bypass bed

d. Carbon Canister Purges To:
   - Air cleaner
   - Carburetor
   - PCV.

e. Other

C. Classification of Systems

Evaporative Control Systems have been divided into two general categories: (1) those using a charcoal canister, and (2) those using a system other than a charcoal canister for storage of fuel tank vapors. Over 98% of the 1973-1975 vehicle population utilize a charcoal canister. These systems have been further typed according to carburetor storage and type of canister purge. This is shown in Figure 5. Systems not using a charcoal canister may use the engine crankcase or a small auxiliary tank for storage.

A further subdivision is by the style of canister. A description of the charcoal canisters used by each U.S. manufacturer is given in Table I.

D. Survey of ECS's in Use

A cross section of about 120 vehicles from the 1973-1975 car population has been used in this survey of evaporative control systems in current use. In addition to describing the ECS, the fuel system components which affect their function such as proximity of fuel tank to a heat source such as muffler, and use of a fuel vapor return line to the tank have also been surveyed. This survey covered all families of engines from each U.S. manufacturer and the leading foreign-manufactured cars. All told, this group is representative of at least 99% of the vehicles in the 1973-1975 car population. The results from this survey are shown in Appendix I.

FIGURE 5

CLASSIFICATION OF EVAPORATIVE EMISSION CONTROL SYSTEMS

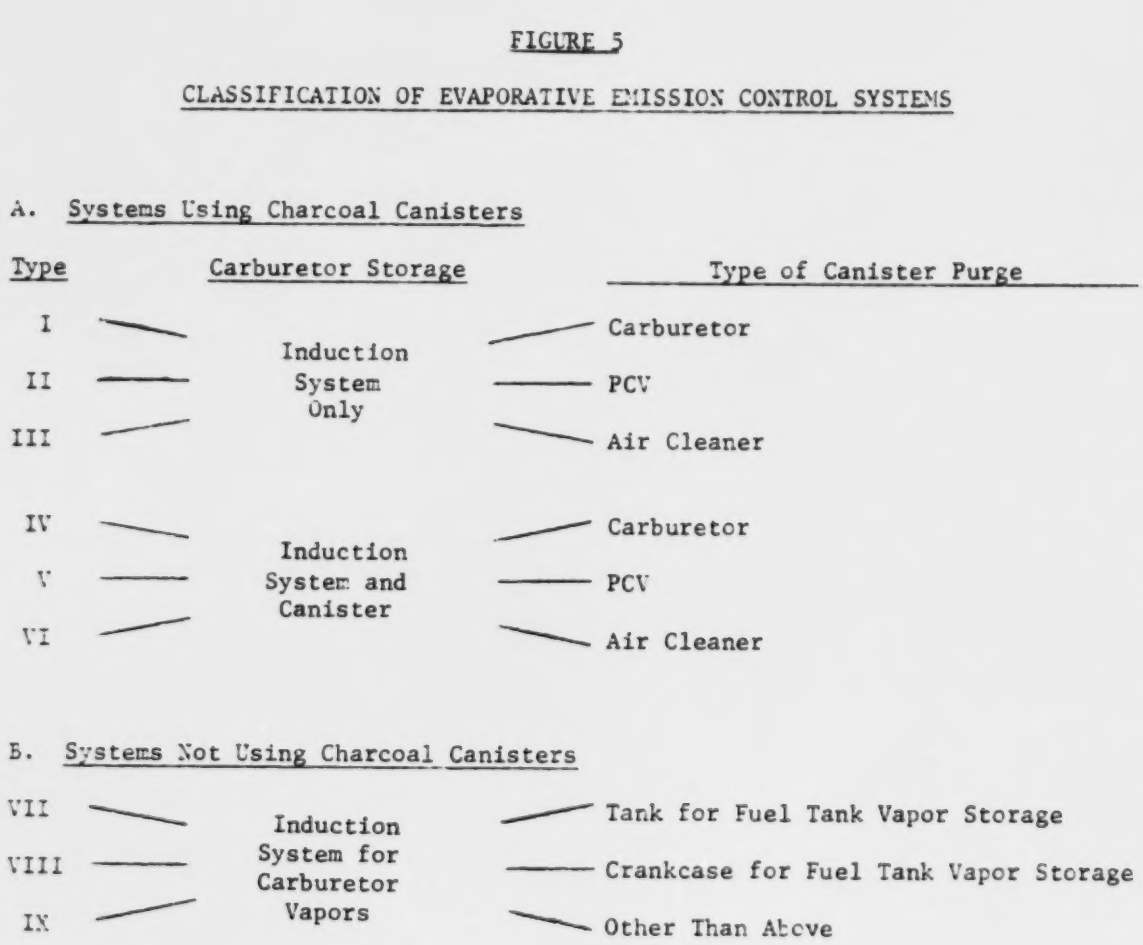


TABLE I

CHARCOAL CANISTERS ON U.S. CARS

Manufacturer	No.	No. of Tubes	Tube Designation			Remarks
			Inlet	Outlet	Other	
General Motors	1	2	Tank	Purge		
	2	3	Tank Carburetor Bowl	Purge		
	3	3 (purge valve)	Tank	Purge	Vacuum for Purge Valve	
	4	4 (purge valve)	Tank Carburetor Bowl	Purge	Vacuum for Purge Valve	
Chrysler	1	3	Tank Carburetor Bowl	Purge		Carburetor Bowl sometimes not used
	2	4 (purge valve)	Tank Carburetor Bowl	Purge	Vacuum for Purge Valve	
Ford	1	2	Tank	Purge		300 gms
	2	2	Tank	Purge		500 gms
	3	3	Tank Carburetor Bowl	Purge		700 gms
American Motors	1	2	Tank	Purge		
	2	3	Tank Carburetor Bowl	Purge		

IV. MAGNITUDE AND SOURCE OF EVAPORATIVE EMISSIONS FROM CURRENT VEHICLES

This part of the program evaluated the effectiveness of the evaporative control systems in current use on U.S. and imported cars.

A. Test Fleet and Test Method

1. Vehicles

The twenty vehicles selected for testing are described in Table II. The criteria for their selection were: (1) to be representative of the control techniques in use, (2) to represent carburetor designs and fuel tank volumes in the field, and (3) be a cross section of the nation's 1973-1975 car population. All vehicles were at least 90 days old prior to the test date. The source of each vehicle is shown in Table III. As far as possible, non-undercoated vehicles were used. Prior to completion of the last phase of this program, it was necessary to return Car No. 3 and replace it with Car No. 21 which was similar in make, model and engine to its predecessor.

2. Vehicle Preparation

Each vehicle underwent a mechanical inspection and was tuned to factory specifications in cases where the ignition system and exhaust emissions were abnormal. For this, the ignition system was checked by an electronic analyzer and the exhaust emissions by the diagnostic procedure[1] developed by Exxon Research for tail pipe CO and HC emissions at idle and 2500 rpm.

Other preparation involved thermocouple installations in the carburetor bowl, the underhood area, and the fuel tank. The thermocouple for underhood temperatures was located about four inches in front of the carburetor bowl. In addition to the in-tank thermocouple required by the SAE J171a test method, a skin type was attached to the outside of the tank at the fuel-air interface. A new fuel tank was used for each vehicle. Two lines were welded into the tank, a drain line and a line from the vapor space in top of the tank. This latter line is for a transducer connection to monitor fuel tank pressure during the diurnal and hot soak cycles. The integrity of the fuel tank system was checked prior to the initiation of the test.

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(1) J. Panzer, "Idle Emissions Testing - Part II," SAE Paper 740133

TABLE II

VEHICLES FOR SHED TESTS
(All Automatic Transmission Except #19)

Car No.	Make	Model	Yr.	Displ. Litres	Displ. Cu. In.	No. Cyl.	No. Venturis	Fuel Tank Litres	Fuel Tank Gals.	Air Cond.	Vapor Return Line?	Undercoated	ECS Type[1]
1	Ford	LTD	75	5.75	351	8	2	92	24	Y	N	N	VI
2	Pontiac	G.P.	75	6.56	400	8	4	95	25	Y	Y	N	I
3	Chrysler	NYer	75	7.21	440	8	4	100	26.5	Y	Y	Y	IV
4	Ford	Pinto	74	2.00	122	4	2	49	13	N	N	N	III
5	Chevrolet	Nova	74	4.10	250	6	1	79	21	Y	N	N	II[2]
6	Chevrolet	Impala	74	5.74	350	8	2	98	26	Y	N	Y	I
7	Plymouth	Duster	73	3.69	225	6	1	60	16	Y	N	Y	IV
8	Buick	Le Sabre	75	5.74	350	8	4	98	26	Y	Y	Y	I
9	Chevrolet	Vega	75	2.29	140	4	2	60	16	N	N	Y	V[2]
10	Oldsmobile	98	74	7.46	455	8	4	98	26	Y	Y	Y	I
11	AMC	Hornet	74	3.80	232	6	1	64	17	Y	N	Y	III
12	Plymouth	Fury III	73	5.90	360	8	2	98	26	Y	N	Y	IV
13	Dodge	Dart	74	5.21	318	8	2	60	16	Y	N	Y	I
14	Datsun	610	74	1.95	119	4	2	52	14	Y	Y	Y	VIII
15	Mazda	RX-4	74	1.31	80	Rotary	4	64	17	Y	Y	Y	VII[3]
16	Mercury	Comet	74	4.10	250	6	1	60	16	Y	N	N	III
17	Volvo	144	74	1.98	121	4	F.I.[4]	60	16	N	Y	N	IX[5]
18	Ford	Squire	75	7.54	460	8	4	79	21	Y	Y	Y	VI
19	VW	Beetle	75	1.60	97	4	F.I.[4]	40	10.5	N	Y	N	IX[6]
20	Mercury	Monarch	75	4.95	302	8	2	73	19	Y	Y	Y	III

(1) Type of Evaporative Control System (ECS) described in Figure 5.
(2) Canister has a purge control valve.
(3) Also uses a carbon canister for fuel tank vapor storage.
(4) Fuel injection.
(5) Carbon canister for fuel tank vapor storage.
(6) Condensor tank for fuel tank vapor storage.

TABLE III

SOURCE OF VEHICLES

Car No.	Make	Source
1	LTD	Leased
2	Pontiac	Leased
3	Chrysler	Leased
4	Pinto	Leased
5	Nova	Private Owner
6	Chevrolet	Private Owner
7	Duster	Private Owner
8	Buick	Private Owner
9	Vega	Private Owner
10	Olds	Private Owner
11	Hornet	Private Owner
12	Plymouth	Private Owner
13	Dart	Private Owner
14	Datsun	Private Owner
15	Mazda	ERE Car
16	Comet	Private Owner
17	Volvo	Private Owner
18	Ford	Private Owner
19	VW	Leased
20	Monarch	Leased
21	Chrysler	Private Owner

3. SHED Procedure

Evaporative losses were measured using the Sealed Housing for Evaporative Determinations (SHED) procedure as described in SAE Recommended Practice J171a. This method employs an enclosure in which the vehicle is placed during diurnal and hot soak phases of the test. Vapors escaping from the vehicle are retained in the enclosure and the increase in the hydrocarbon concentration of the atmosphere in the enclosure represents the evaporative emissions.

Details for the SHED test are outlined in SAE J171a. These were followed in this work with one or two exceptions such as for preconditioning. Some of the operational steps for the test are covered below:

Preconditioning:

The preconditioning procedure for this test was as follows: (1) three consecutive LA-4(1) cycles [7.5 mile (12.1 km) trips], (2) shut down for 10 minutes, and (3) a fourth LA-4 cycle. This was followed by an 11-16 hour soak at about 24°C.

Diurnal Cycle:

A one hour soak in the SHED during which the temperature of the fuel in the tank is raised from 60 to 84°F (15.6 to 28.9°C). A pressure transducer was used to monitor fuel tank pressure during the diurnal cycle and the hot soak.

Federal Test Cycle:

The vehicle was quickly placed on the cnassis dynamometer after the diurnal cycle for an exhaust Federal Test Procedure. The dynamometer had previously been warmed up with a different vehicle and the load set.

Hot Soak:

A one hour hot soak in the shed followed immediately after the Federal cycle to complete the test.

The fuel for the SHED test was Indolene of 9.0 psi (62.1 kPa) RVP. Inspections for this fuel are shown in Appendix II.

(1) 1972 Federal Test Procedure

4. Test Sequence

The sequence of testing for each vehicle is outlined in the diagram in Figure 6. Those vehicles which emitted less than 2 grams/test were tested a second time by the SHED procedure to complete their test cycle. All vehicles failing the 2 gram limit underwent a source test to determine the location of the leaks. This was followed by two tests to quantify the emissions from individual leak sources using the technique described in Appendix III. A third quantifying test was made in cases where there was an abnormal variance between the first two tests. This was followed by a second SHED test to complete the testing schedule. (Hot and cold background tests were also carried out on each vehicle as per SAE J171a.)

B. Evaporative Emissions from 1973-75 Cars

1. Total Evaporative Losses from Vehicles

Total losses, as measured by the SHED procedure, varied from a low 0.5 gram to a high of 30.6 grams for the 20 car group. The average for the group was 8.7 grams. The range for the 20 cars is shown graphically below:

TOTAL EVAPORATIVE LOSSES
20 Cars

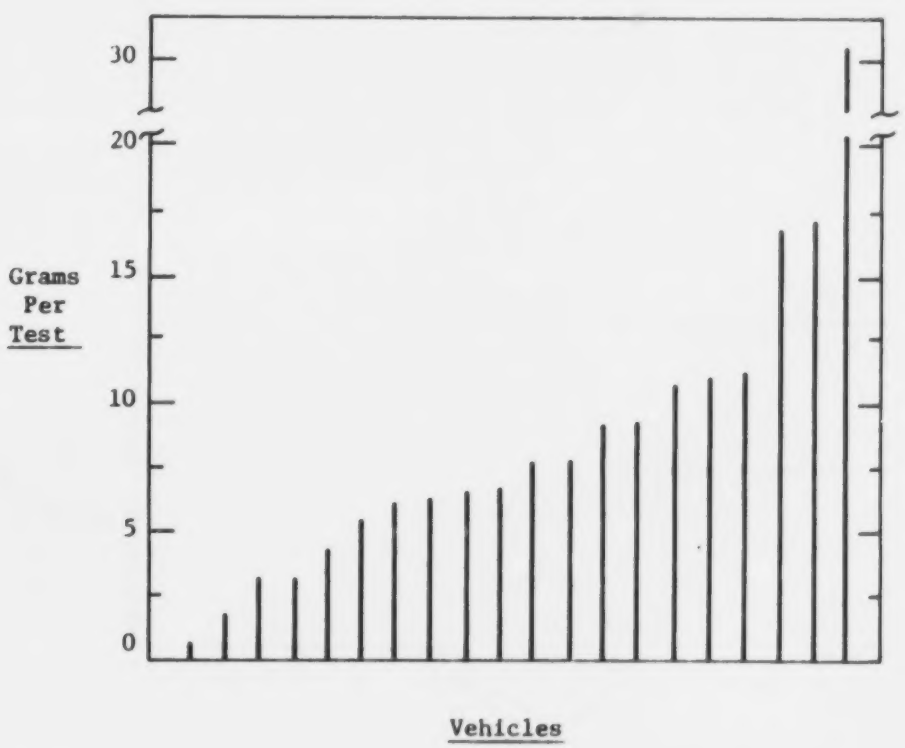
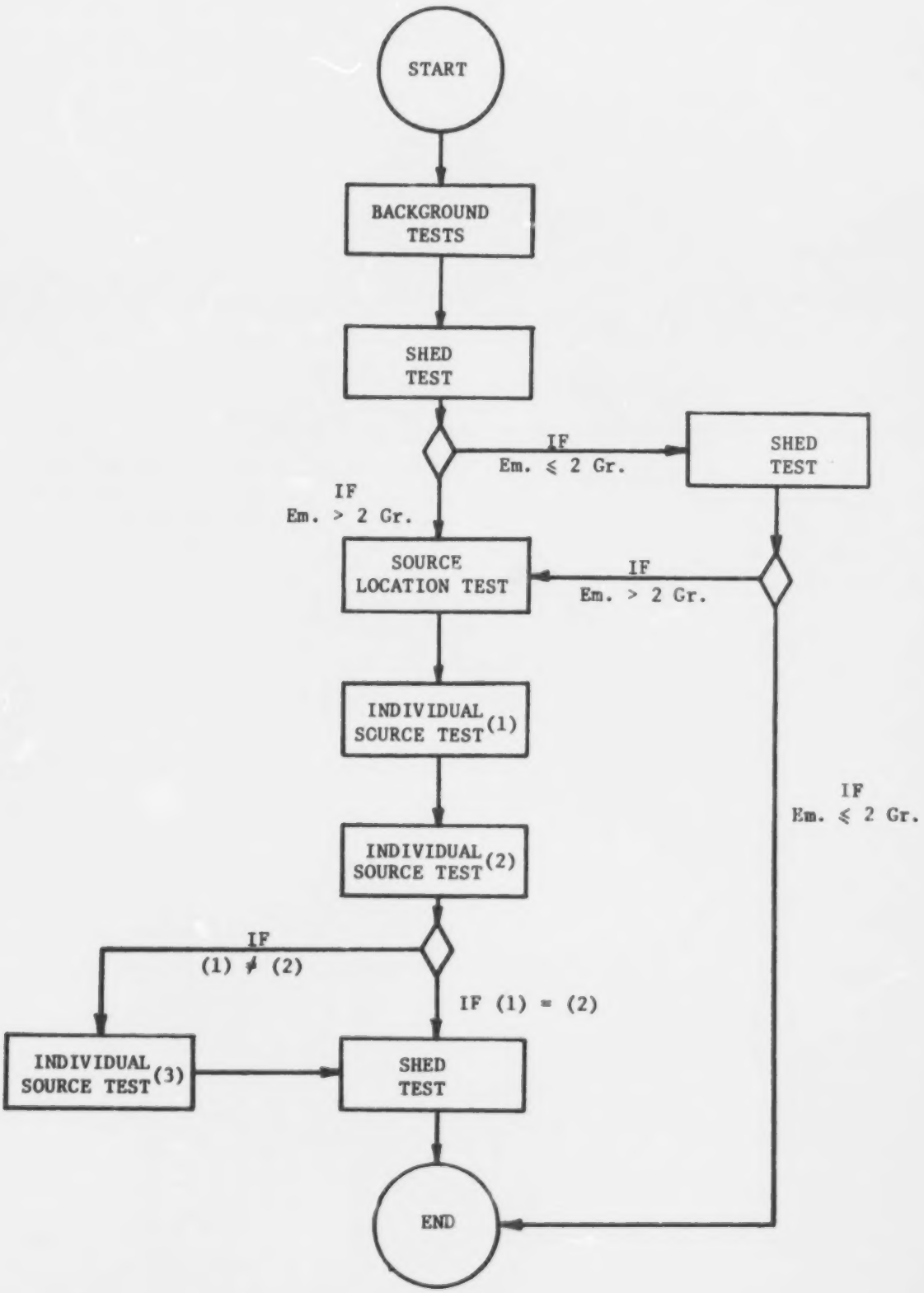


FIGURE 6

FLOW DIAGRAM OF TESTING PROCEDURE



In this program, the data are for the most part an average of two SHED tests. The initial test may be slightly higher than the second SHED test because leaks in the air cleaner were sealed prior to the second test (as part of the quantifying procedure). In cases where there was a substantial difference between the two SHED tests, a third was run and the three averaged for the vehicle. The total evaporative loss was adjusted for vehicle background hydrocarbon levels. The results for individual runs on each car are summarized in Appendix IV.

The table below shows total evaporative losses by make and model in descending order from worst to best. No particular U.S. manufacturer appears to stand out from a good performance standpoint. A Plymouth Duster was the best U.S. car, however, the Chrysler NYer is one of the poorest for high evaporative losses. Some models from both G.M. and Ford also are comparatively good and others fall in the poor category. The best vehicle was a fuel injected VW Beetle with only 0.5 gram total evaporative loss. The other fuel injected vehicle in the group, the Volvo, falls in the poorest half of the 20 car group.

Table IV

Total Evaporative Losses By Make and Model

Total Loss Grams	Make	Model	Yr.	Car No.	ECS Type(1)
30.6	Ford	Country Squire	75	18	VI
17.3	Mercury	Comet	74	16	III
17.1	Chrysler	NYer	75	3	IV
10.9	Chevrolet	Nova	74	5	II
10.7	AMC	Hornet	74	11	III
10.6	Mazda	RX-4	74	15	VII
9.5	Olds	98	74	10	I
9.3	Mercury	Monarch	75	20	III
7.5	Volvo	144	74	17	IX
7.5	Pontiac	G.P.	75	2	I
6.7	Ford	LTD	75	1	VI
6.6	Buick	Le Sabre	75	8	I
6.0	Ford	Pinto	74	4	III
5.8	Plymouth	Fury III	73	12	IV
5.3	Chevrolet	Impala	74	6	I
4.1	Chevrolet	Vega	75	9	V
2.8	Dodge	Dart	74	13	I
2.8	Datsun	610	74	14	VIII
1.5	Plymouth	Duster	73	7	IV
0.5	VW	Beetle	75	19	IX

(1) ECS type described in Figure 5.

No single type of ECS system appears to be superior to the others in the above table. There are, however, desirable features from individual ECS systems which will be discussed later.

2. Background Data

Evaporative losses from sources other than the fuel system are generally small. Cold background data for U.S. vehicles fall in the range of 0.0 to 0.2 grams per test. Hot backgrounds were higher ranging for 0.0 to 0.7 grams per test. Table V and Appendix IV show individual vehicle background data. The only car to have a high background from a non-fuel oriented source was the 1975 VW, Car No. 19. The background levels of this vehicle were 0.7 and 0.8 grams cold and hot respectively. These do not appear to be the result of gasoline absorption from previous spillage on the vehicle as was the case for several test cars. Both the hot and the cold background tests were continued for 24 hours. The rate of hydrocarbon emission did not diminish significantly during the 24 hour periods. Comprehensive probing for the source of hydrocarbon emission did not reveal any sources. Additional testing showed that essentially all of the hydrocarbon was coming from the outside of the vehicle and only a small fraction from the interior. This vehicle is at least 5-6 months old. It appears that the paint may be the source of the emission.

3. Evaporative Losses by Mode of Operation (Test Cycle)

The bulk of the evaporative losses occur during the hot soak mode of operation. Evaporative losses by mode of operation are shown in Table VI. For the U.S. cars in this group, 83% of the evaporative loss was experienced during the hot soak. This means that most U.S. cars handle fuel tank vapors from the diurnal cycle satisfactorily in their carbon canister storage system. The loss during the diurnal cycle for 70% of the U.S. cars was 10% or less of the total loss. For the remaining U.S. cars, diurnal losses were as high as 65% of the total loss. Imported vehicles follow the same pattern as the U.S. car population.

4. Evaporative Losses by Individual Sources

a. Overflow from the Carburetor Storage System

Hydrocarbon vapors escaping from the air cleaner during the hot soak are by far the largest contributor to evaporative losses. One half of the hydrocarbon loss is by this route with vapors escaping from the air cleaner snorkel. This indicates that the air cleaner and induction system do not have sufficient capacity to store all of the vapors emitted from the carburetor bowl during shut down. A summary of the contribution from each source to the total emission for the cars is shown in Table VII along with the mode of operation during which the loss occurs. The source of losses for individual vehicles is summarized in Table VIII.

TABLE V

EVAPORATIVE LOSSES ADJUSTED FOR BACKGROUND

Car No.	Total Loss Before Background Adjustment, Grams	Background, Grams		Total Loss Adjusted for Background, Grams
		Cold	Hot	
1	6.7	--(1)	--(1)	6.7
2	7.5	--(1)	--(1)	7.5
3	17.2	0.0	0.1	17.1
4	6.2	0.0	0.2	6.0
5	11.0	0.0	0.1	10.9
6	5.3	--(1)	--(1)	5.3
7	1.5	--(1)	--(1)	1.5
8	7.0	0.1	0.3	6.6
9	4.7	0.0	0.6	4.1
10	10.0	0.2	0.3	9.5
11	10.8	0.0	0.1	10.7
12	6.6	0.1	0.7	5.8
13	2.9	0.0	0.1	2.8
14	3.1	0.1	0.2	2.8
15	12.2	0.5(2)	1.1(2)	10.6
16	17.4	0.0	0.1	17.3
17	7.7	0.1	0.1	7.5
18	30.7	0.0	0.1	30.6
19	2.0	0.7(3)	0.8(3)	0.5
20	9.3	0.0	0.0	9.3

(1) No background data for these cars. The results from the background tests for Cars No. 1, 2, 6 and 7, which were the first four to be tested for background, were very high due to gasoline spillage on the front carpet. A fuel can had been used as an auxiliary fuel tank. This took place after the SHED testing. Procedure changed after these four cars.

(2) Evidence of gasoline spillage in the trunk prior to the SHED tests, which would account for the high background.

(3) Appears to be coming from external enamel paint.

TABLE VI

EVAPORATIVE LOSS BY MODE OF OPERATION

Car No.	Total Loss, Grams	% of Loss	
		Diurnal Cycle	Hot Soak
1	6.7	50	50
2	7.5	5	95
3	17.1	45	55
4	6.0	30	70
5	10.9	2	98
6	5.3	10	90
7	1.5	-	---
8	6.6	10	90
9	4.1	5	95
10	9.5	5	95
11	10.7	5	95
12	5.8	65	35
13	2.8	5	95
14	2.8	35	65
15	10.6	0	100
16	17.3	0	100
17	7.5	60	40
18	30.6	5	95
19	0.5	-	--
20	9.3	20	80

TABLE VII

SUMMARY OF SOURCES OF EVAPORATIVE LOSSES FROM 20 CAR GROUP

Location	Mode	% of Total Losses
1 - Air Cleaner(1)	Hot Soak	50
2 - Carburetor Leaks(2)	Hot Soak	25
3 - Carbon Canister	Diurnal	10
4 - Carbon Canister	Hot Soak	10
5 - Other	Diurnal & H.S.	5

(1) Snorkel - other leaks sealed before tests.

(2) Primarily from around accelerator pump shaft. Some smaller leaks elsewhere.

TABLE VIII

SOURCES OF EVAPORATIVE LOSSES

Car No.	Total Loss, Grams	% of Total Evaporative Loss					
		Air Cleaner		Carbon Canister			
		Diurnal Cycle	Hot Soak	Diurnal Cycle	Hot Soak	Carb. Leakage	SHED(1)
1	6.7	0.0	0.0	45	45	0.0	10
2	7.5	0.0	60	5	5	25	5
3	17.1	0.0	20(2)	45(2)	20(2)	10	5
4	6.0	0.0	65	30	0.0	0.0	5
5	10.9	0.0	45	0.0	0.0	50(3)	5
6	5.3	0.0	95	0.0	0.0	0.0	5
7	1.5	--	--	--	--	--	--
8	6.6	0.0	70	0.0	0.0	25	5
9	4.1	0.0	90	0.0	0.0	0.0	10
10	9.5	0.0	75	0.0	0.0	20	5
11	10.7	0.0	40	0.0	0.0	60	0.0
12	5.8	0.0	0.0	35	35	30	0.0
13	2.8	0.0	60	0.0	0.0	35	5
14	2.8	15(2)	0.0	--	--	45	40(5)
15	10.6	0.0	100	--	--	0.0	0.0
16	17.3	0.0	85	0.0	0.0	15	0.0
17	7.5	5	50	0.0	0.0	35(4)	10
18	30.6	0.0	20	0.0	10	65	5
19	0.5	--	--	--	--	--	--
20	9.3	0.0	25	20	0.0	50	5

(1) Hydrocarbon vapors not collected in quantifying test or otherwise accounted for.

(2) Estimated.

(3) This carburetor also externally vented upon slight pressure in bowl.

(4) Leakage from gas cap.

(5) Crankcase storage.

The vehicles with the lowest loss from the air cleaner were those utilizing both canister and air cleaner storage for vapors from the carburetor bowl. These are Type IV-VI systems. Using the canister to handle part of the hot soak load alleviates the overloading of the air cleaner. However, unless the canister has sufficient working capacity to adsorb the added load, it in turn will overflow.

b. Carburetor Leaks

This is the second largest contributor to evaporative losses and accounts for 25% of the total loss. For the most part, these leaks occur in carburetors which do not utilize a diaphragm type of accelerator pump (used in Ford Motor Company and some other carburetors). Sixty percent of the cars tested had problems with hydrocarbon leakage around the accelerator pump shaft where it passes through the air horn or body of the carburetor. Car No. 5, in addition to leakage around the accelerator pump linkages, vented to the atmosphere with a slight pressure buildup in the carburetor bowl.

c. Overflow from the Charcoal Canister

This is the third largest source of evaporative emissions with 10% occurring during the diurnal cycle and an additional 10% during the hot soak. This indicates insufficient working capacity in the canister of five of the twenty cars in the group. Vehicles with overflow during the hot soak utilized the carbon bed to store carburetor bowl vapors as well as fuel tank vapors.

d. Other Losses

Some hydrocarbon is lost from small leaks such as from the ends of the throttle shaft as it passes through the carburetor body and other places. Running losses during the Federal Cycle were not measured. The most likely source of running vapors is venting through the gas cap due to pressure build-up in the tank. Car No. 17 was the only vehicle to have a significant pressure build-up in the fuel tank. It vented hydrocarbon vapors through the gas cap during the diurnal cycle and hot soak and probably during the Federal Cycle.

V. MODIFICATION OF VEHICLES FOR LOWER EVAPORATIVE EMISSIONS

The purpose of this phase of the program is to develop hardware to give better control of emissions, select vehicles with typical or representative sources of evaporative emissions, and then to modify the vehicles to demonstrate the effectiveness of the new hardware.

A. Hardware for Better Control of Evaporative Emissions

1. Air Cleaner Overflow

Five techniques to control air cleaner overflow during the hot soak are shown as Controls No. 1 through 5 in Table IX and discussed below:

Control No. 1 - Vent the Carburetor Bowl to the Canister

A portion of the hot soak emissions is directed to the carbon canister for storage in lieu of the air cleaner. A valve in the carburetor opens to vent the bowl to the canister during idle and shutdown. At other times, the vent line is closed. Venting of the bowl to the canister is now used in the ECS's of Vehicles No. 1, 3, 9, and 12. This modification requires minimum flow resistance in the line to the canister, viz. line should slope toward the canister and be of adequate size to handle the vapor load. Undue resistance to flow results in excessive hydrocarbon vapors entering the air cleaner via the carburetor bowl balance tubes. This modification requires a larger storage capacity in the carbon canister than ECS's with air cleaner storage only for hot soak emissions. The canister must now accommodate both the hot soak and the diurnal emissions at the same time.

Control No. 2 - Ventilating Engine Compartment with a Fan

A fan is used to provide cool air to the engine compartment to lower the temperature increase of the bowl during the hot soak. The lower bowl temperature contributes to a decrease in hot soak emissions and lessens the load on the storage system. The fan can be actuated by a thermal switch through the ignition system. This will cool the engine compartment until its temperature is lowered to the control point at which time the fan is shut off.

Control No. 3 - Barrier at the Base of the Air Cleaner Snorkel

Hydrocarbon vapors are heavier than air and tend to preferentially settle down. A barrier at the base of the snorkel deters the loss of emissions out the snorkel.

Other controls to limit air cleaner overflow such as decreasing carburetor bowl volume and use of louvers in the hood for ventilation are suggested in Table IX. They were not included in this program.

TABLE IX

METHODS FOR CONTROL OF EVAPORATIVE EMISSIONS

Control No.	Source	Description	Remarks
1*	Air cleaner overflow	Vent carburetor bowl to canister.	
2*	Air cleaner overflow	Ventilating engine compartment with a fan during hot soak.	Less vapors generated because of lower carburetor bowl temperatures.
3*	Air cleaner overflow	Barrier at base of snorkel.	
4	Air cleaner overflow	Decrease bowl working volume.	Less vapors generated.
5	Air cleaner overflow	Louvers in hood for ventilation.	Less vapors generated.
6*	Canister overflow	Increase size of carbon bed.	Two canisters used in parallel.
7*	Canister overflow	Increase purge rate.	
8*	Canister overflow	Close bottom of canister and vent to top of unit.	
9*	Canister overflow	Control No. 2	Apply for ECS with carburetor bowls vented to the canister.
10	Canister overflow	Controls No. 4 and 5	For ECS's with vented bowls to the canister.
11	Canister overflow	Heat purge air.	
12*	Canister overflow	Minimize heat input to fuel tank. Shield tank from hot muffler, etc.	Less vapors generated.
13	Canister overflow	Minimize vapor space in the fuel tank.	
14*	Carburetor leaks	Close spaces around shafts with boots, caps, etc.	
15	Carburetor leaks	Use a diaphragm type accelerator pump in lieu of the plunger type.	

*Controls demonstrated in this program.

2. Carbon Canister Overflow

Eight techniques are suggested for control of an overloaded carbon canister. These are shown as Control 6 through 13 on Table IX and described below:

Control No. 6 - Increase Size of Carbon Bed

This modification will increase the working capacity of the system. (Working capacity is the maximum weight of hydrocarbon that can be handled in the storage unit.) In many cases, it is not necessary to increase purge rate to realize an increase in working capacity with a larger canister. This is the case because, even though the purge flow rate is lower per unit of charcoal with a larger bed, the average hydrocarbon loading on the charcoal during the purge cycle is higher, resulting in more hydrocarbon being removed from the canister.

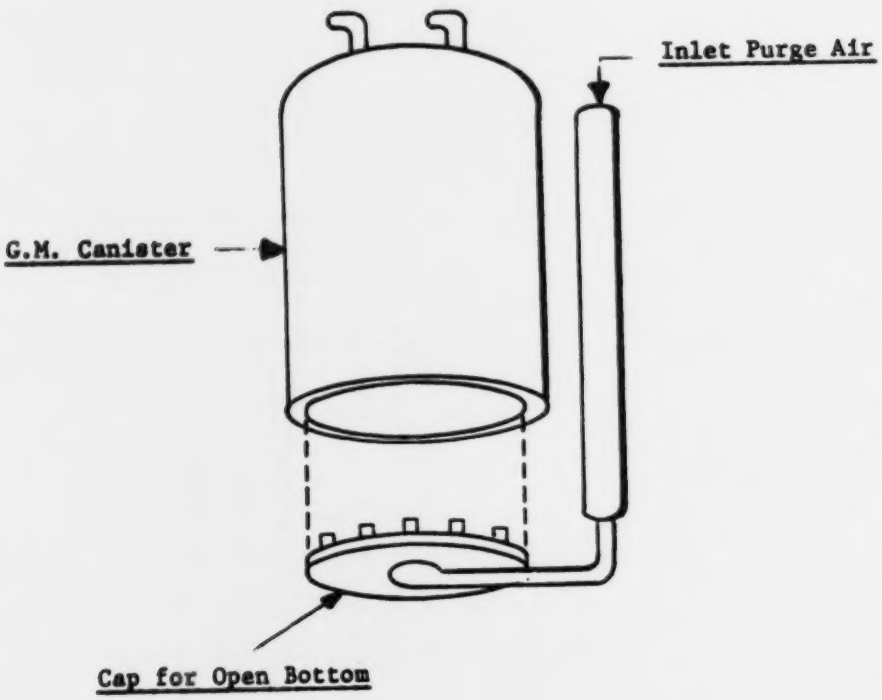
Control No. 7 - Increase the Purge Rate

This technique will increase the working capacity of those canister storage units which currently have low purge rates. ECS's which utilize air cleaner purge systems, Type III and VI, generally have low purge volumes. In many instances, it may be necessary to utilize carburetor or PCV purge systems to raise the purge volume to the desired level.

Control No. 8 - Close the Bottom of Open Canisters

This would prevent seepage or migration of hydrocarbon from the bottom of the open canister. A sketch of a cover with a vent pipe is shown on the following page.

CAP PREVENTS LOSS FROM BOTTOM OF CANISTER



Controls No. 10 through 13 in Table IX outline additional controls to handle canister overflow. These controls were not used in this program with exception of Control No. 12 which was applied to Vehicle No. 17.

3. Carburetor Leaks

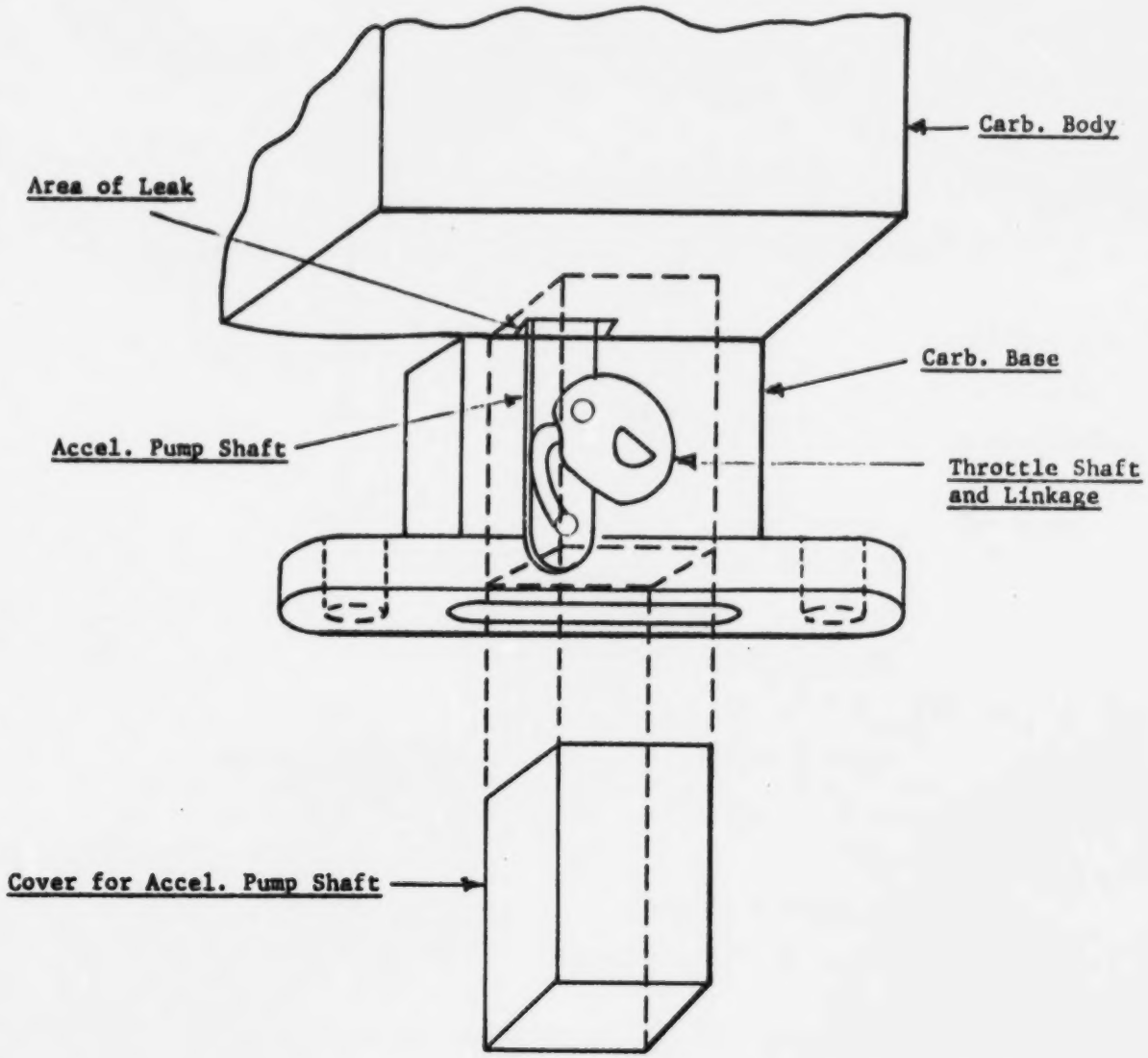
Two controls are suggested for carburetor leaks as indicated below:

Control 14 - Use of Flexible Boot and Covers

Carburetor leaks around accelerator pump shafts can be prevented by use of a flexible boot around the shaft to seal the opening. In cases where a boot will not suffice, a cover such as the one shown in Figure 7 can be used.

FIGURE NO. 7

SKETCH OF A SEAL FOR CARTER CARB. LEAK. - CAR NO. 11



Cover Design: The two sides and bottom would be cast into the carburetor base. Front side would be held in place with a snap clip.

Control 15 - Use of a Diaphragm Type Accelerator Pump

Use of a diaphragm type accelerator pump such as on Ford carburetors in lieu of the piston type on Rochester Products and Carter units will prevent leakage. It will require retooling in most cases.

B. Vehicle Selection and Modification

1. Selection

Six vehicles were selected from the 20 car group for ECS modification. The evaporative emissions and ECS's of these vehicles are representative of the 20 vehicle group. The vehicles ar shown below:

Table X

Vehicles for Modification

Car No.	Make	Year	ECS Type	ECS Purge
1	Ford	75	VI	Air Cleaner
2	Pontiac	75	I	Carburetor
3	Chrysler	75	IV	Carburetor
11	AMC	74	III	A.C. Snorkel
15	Mazda	74	VII	(1)
17	Volvo	74	IX	(2)

(1) Modified Type VII system.
(2) Fuel injected. Canister for tank vapors.

It was necessary to return Car No. 3 before completion of the test. A vehicle of same make, model and year was obtained for completion of the work. This is Vehicle No. 21 in the report.

2. Current Emissions

The following table summarizes the original evaporative emissions of the vehicles selected to be modified:

Table XI

Evaporative Emissions from Six Test Vehicles

Car No.	SHED Test Grams Total	SHED Test % Diurnal	SHED Test % Hot Soak	Emission Source Air Cleaner	Emission Source Canister	Emission Source Carburetor
1	6.7	50	50	N	Y	Slight
2	7.5	5	95	Y	Slight	Y
3	17.1	45	55	Y	Y	Y
11	10.7	5	95	Y	N	Y
15	10.6	0	100	Y	N	N
17	7.5	60	40	Y	N	-
21	13.9	40	60	-	-	-

3. Individual Vehicle Modification for Improved Emission Control

The most promising hardware based on engineering judgment was installed on each test vehicle for the first modification. Additional modifications were then made as necessary to bring the SHED test level to 2.0 grams or less. The modifications were prototype in nature and not a finished hardware. For example, a manually operated clamp on the carburetor vent line performed the job of the carburetor vent valve. (Vent valves were on the factory carburetor for Vehicle No. 1, 3, and 9.) Also, the underhood fan was activated manually.

The primary goal of this work was to demonstrate an ECS system modified to exhibit an emission level of 2.0 grams or less/SHED test. However, no attempt was made to test the longevity of the modifications. In addition, the modified systems were not optimized for best exhaust emissions and/or for driveability. A description of the modifications performed on each of the six vehicles is outlined in Tables XII to XVIII.

Table XII

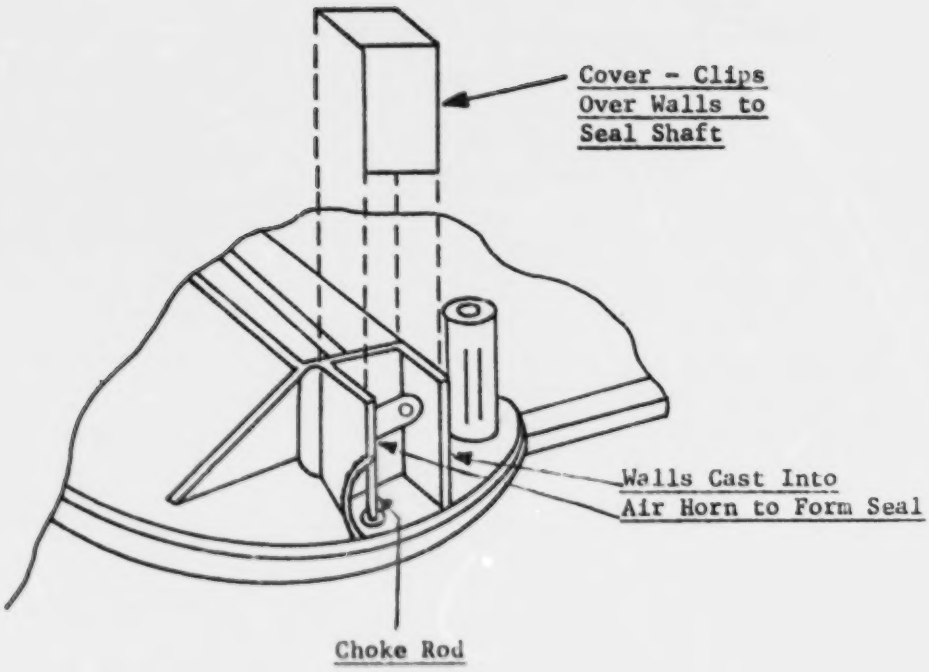
Modification for Vehicle No. 1 - LTD

Component	Factory ECS	Modification
(1) Carbon canister	3 tube Ford (low pressure drop)	Replaced with 4 tube Vega canister with purge control valve. Bottom of canister capped.
(2) Purge	Air cleaner	Changed to PCV purge.
(3) Carburetor	Leak around choke shaft	Cover fitted over leak source(1).
(4) Air cleaner	Leak sources at base of snorkel and other fittings	Sealed with silicone sealant.

(1) Sketch of cover in Figure 8.

FIGURE NO. 8

PROPOSED SEAL FOR CHOKE
ROD PASSAGE THROUGH AIR HORN



Comments:

A PCV purge was installed after flow tests had indicated that air cleaner only and an air cleaner-snorkel combination purge were inadequate. This is discussed in Appendix V. The 4 tube Vega canister was obtained from a 1974 model vehicle in daily service. Photographs of these modifications are shown in Figures 9 and 10.

Table XIII

Modifications for Vehicle No. 2 - Pontiac

Component	Factory ECS	Modification
(1) Carbon canister	Delco 2 tube	Replaced with 3 tube Chrysler canister. Bottom of unit capped.
(2) Purge	Carburetor	No change.
(3) Carburetor	Small leak around accelerator pump shaft.	Boot installed around shaft. Carburetor bowl vented to the carbon canister.
(4) Air cleaner	Small leaks	Leak sources sealed with silicone sealant.
(5) Other	-	Underhood fan installed to ventilate underhood and lower carburetor bowl temperature during hot soak.

Comments:

Underhood fan used to demonstrate the feasibility of decreasing hydrocarbon vapor generation in the carburetor bowl by lowering bowl temperature. No modification of the carburetor purge is required in this installation. See Figures 11 and 12 for details of this installation and also Appendix V.

After completion of tests with the above system, a Vega canister was installed and tests were conducted without use of the underhood ventilating fan. Results of the tests with this system were also less than 2 grams/test.

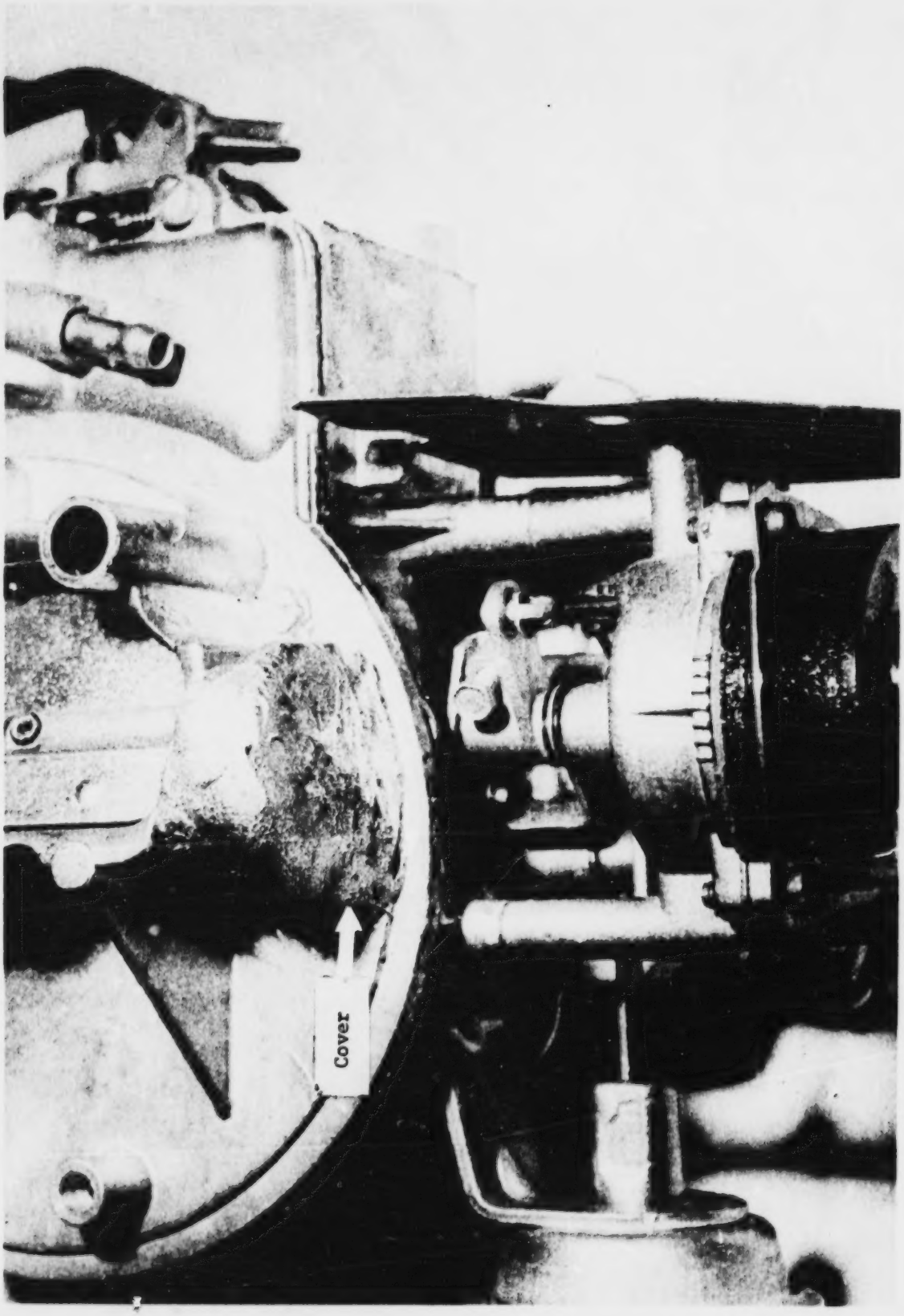


FIGURE 9 COVER OVER CHOKE LINKAGE TO PREVENT HYDROCARBON LEAKAGE ON THE LTD

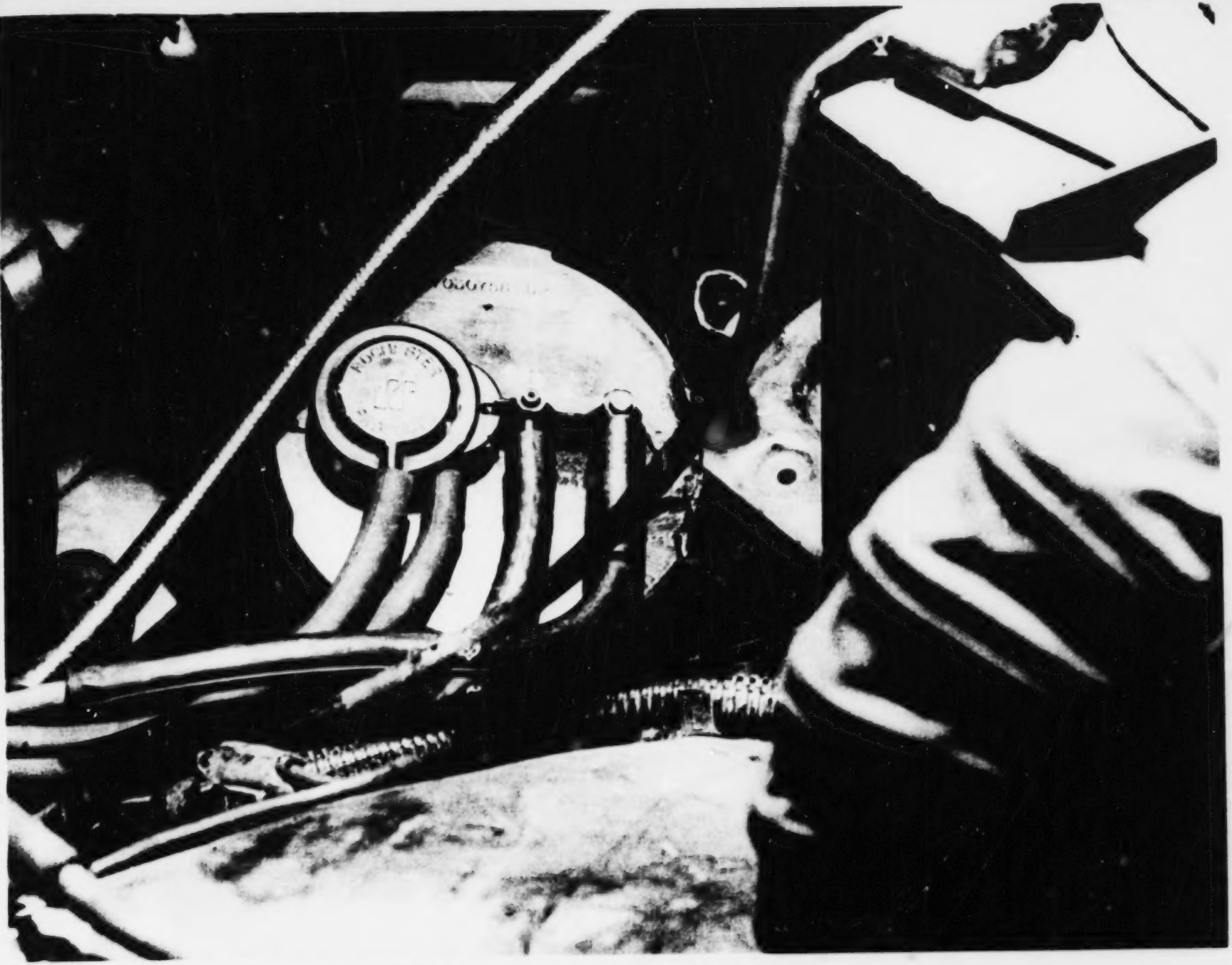


FIGURE 10 FOUR TUBE CANISTER FOR THE LTD

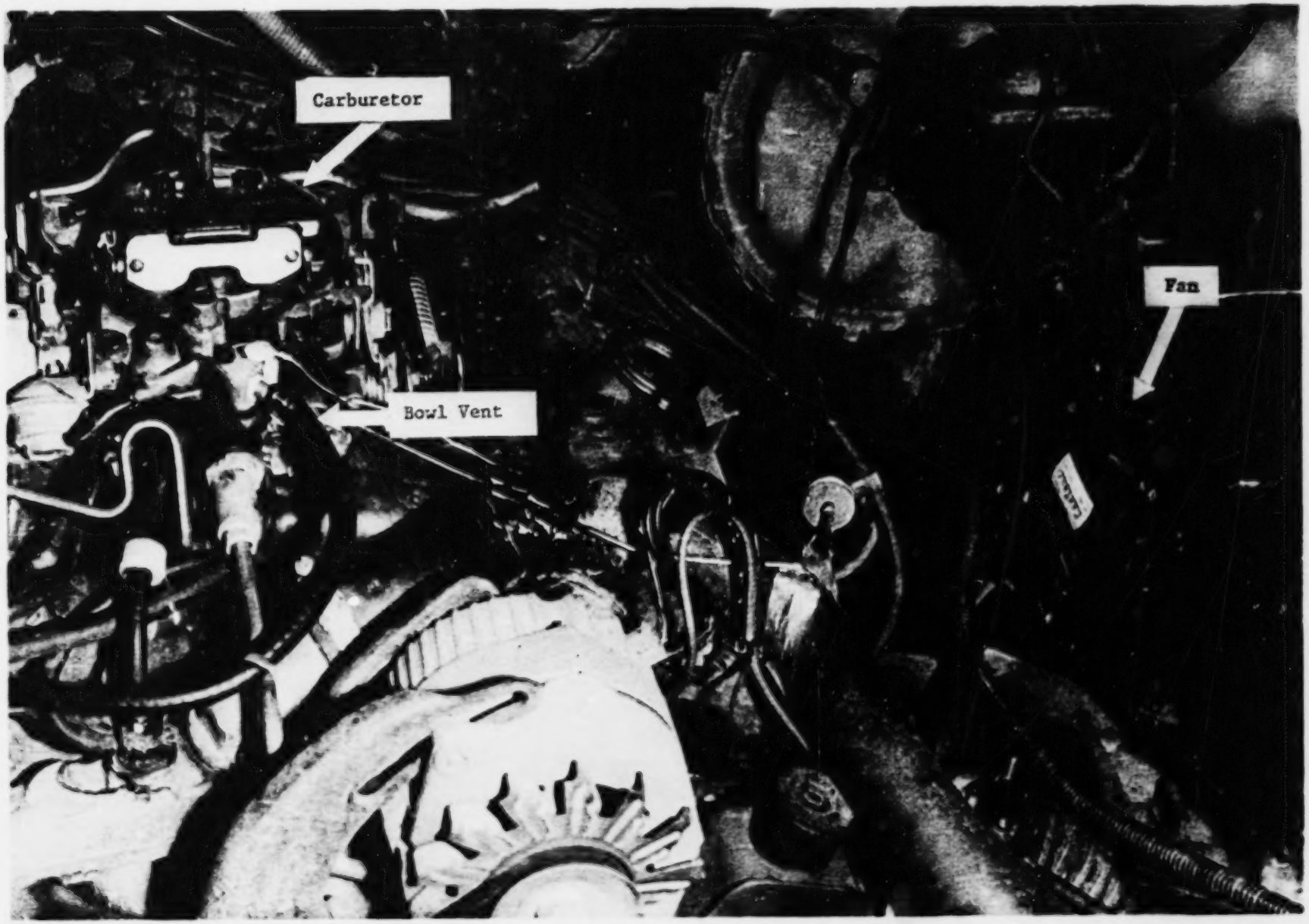


FIGURE 11 FAN FOR UNDERHOOD VENTILATION AND CARBURETOR MODIFICATION FOR THE PONTIAC

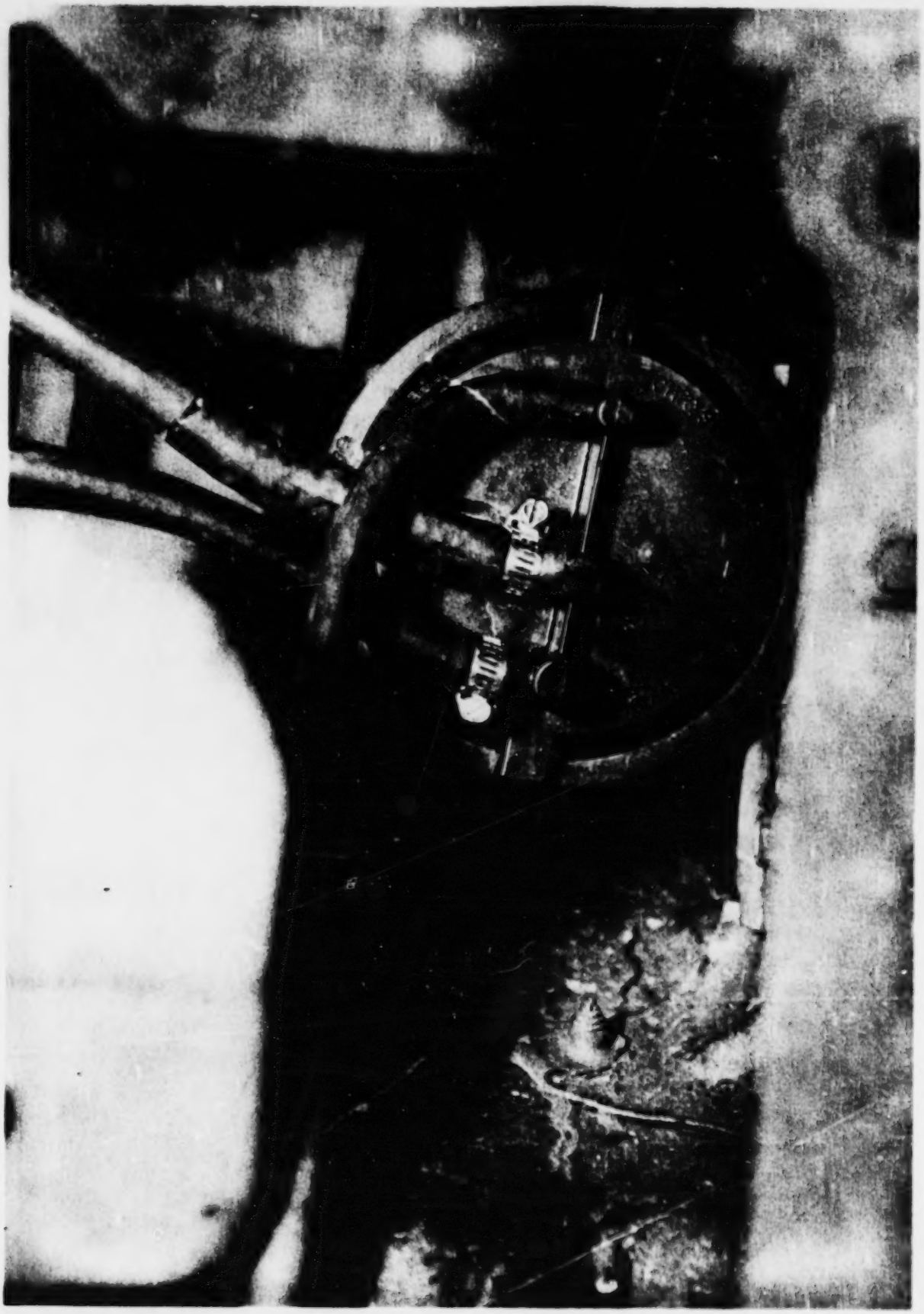


FIGURE 12 CARBON CANISTER (3 TUBE) FOR THE PONTIAC

Table XIV

Modifications for Vehicle No. 21 - Chrysler

Component	Factory ECS	Modification
(1) Carbon canister	One 3 tube	Two 3 tube canisters in parallel were used. Bottoms of canisters capped.
(2) Purge	Carburetor	No change.
(3) Carburetor	Leak around accelerator shaft.	Boot installed. Second carburetor bowl vented directly to canister.
(4) Air cleaner	Some small leaks	Sealed with silicone sealant. Barrier installed at base of snorkel.

Comments:

The large volume fuel tank and the large carburetor bowl volume for this car generate too much hydrocarbon vapor for one standard size canister to handle. (Purge volume is already high.) Consequently, two canisters were utilized. In actual practice, it would be more feasible to use one canister with a larger bed. It was necessary to vent the second carburetor bowl directly to the canister because the balance tubes between the bowls and the air cleaner permitted an excessive amount of vapors to enter the air cleaner with a single vent. Details of this modification are shown in Figures 13 and 14 and Appendix V.

Table XV

Modifications for Car No. 11 - Hornet

Component	Factory ECS	Modification
(1) Carbon canister	2 tube AMC	Changed to a 4 tube Vega with a purge control valve. Bottom capped on canister.
(2) Purge	Air cleaner snorkel	Modified to a PCV system.
(3) Carburetor	Leak around accelerator pump shaft linkage.	Cap installed over linkage.(1) Carburetor bowl vented to canister.
(4) Air cleaner	Several small leaks	Leaks sealed with sealant. Barrier installed at the base of the snorkel.

(1) See Figure 15.

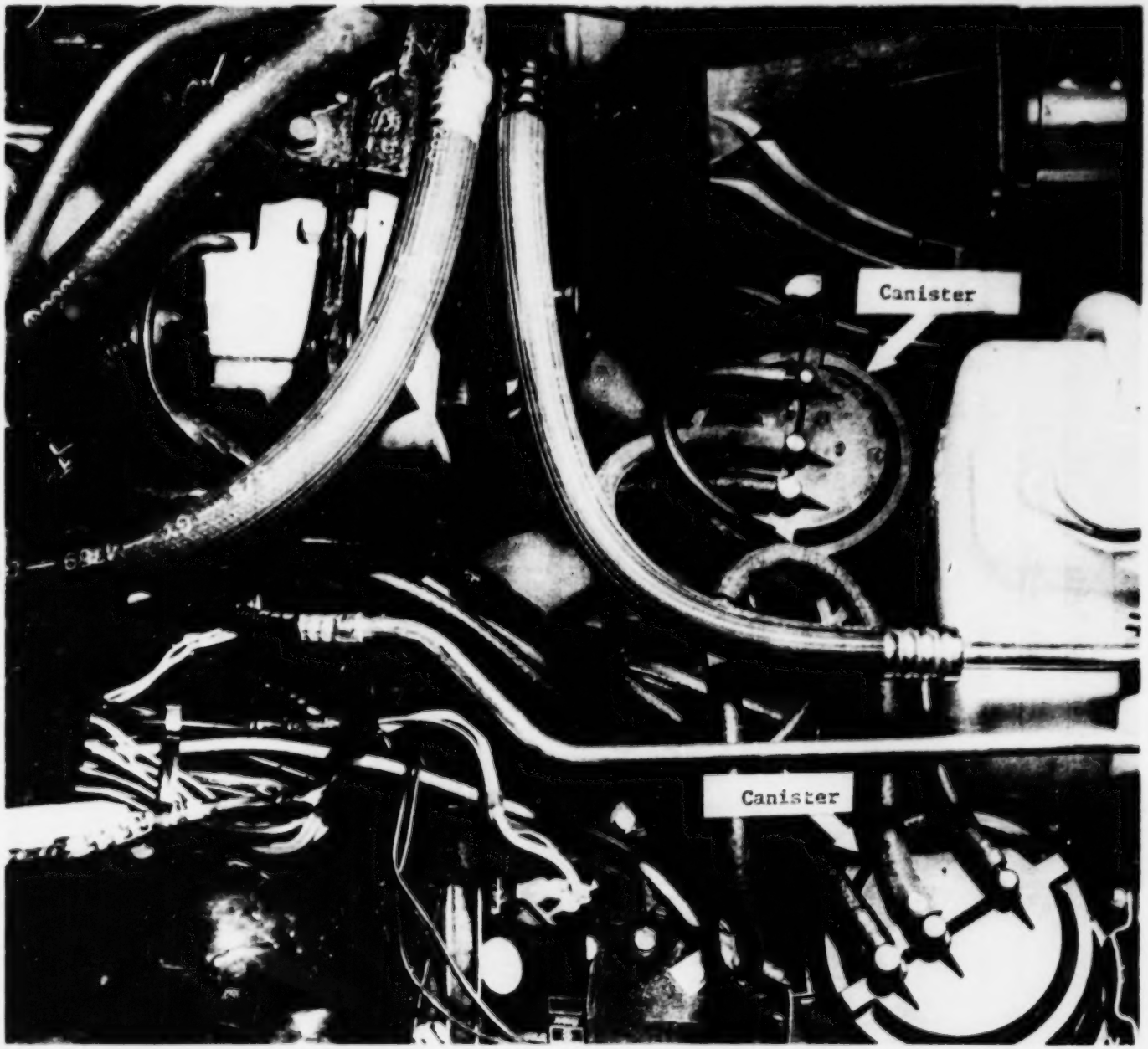


FIGURE 13 DUAL CANISTERS ON THE CHRYSLER

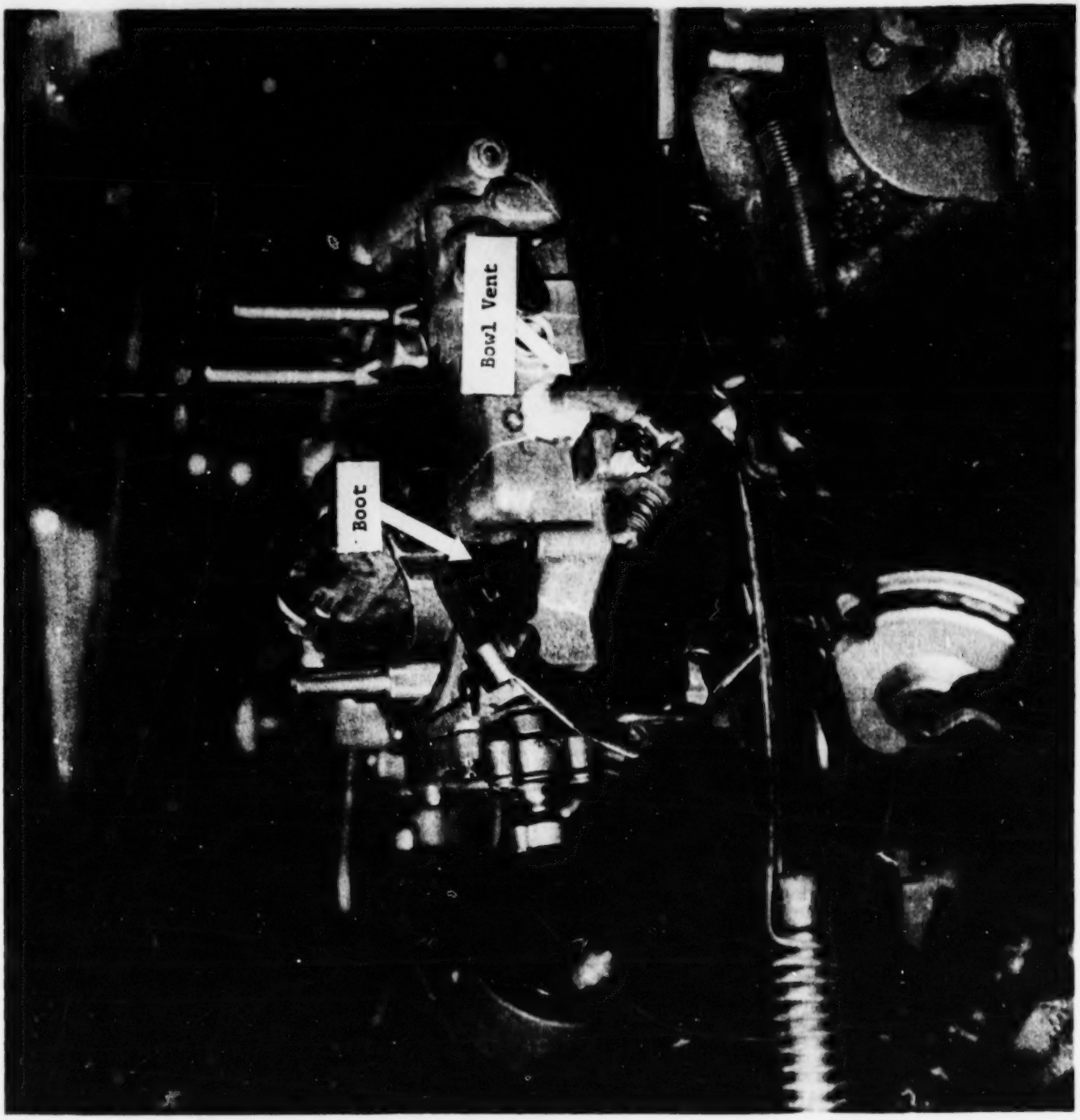


FIGURE 14 CARBURETOR MODIFICATIONS FOR THE CHRYSLER

FIGURE 15 CARBURETOR BOWL VENT AND COVER FOR ACCELERATOR PUMP LINKAGE FOR THE HORNET

Comments:

Purge flow tests indicated insufficient flow rate from the snorkel even with modifications to increase flow. The Vega canister used here was obtained from a 1974 Vega which had been driven daily. See details of this modification in Figures 15, 16, and 17 and Appendix V.

Table XVI

Modifications for Car No. 15 - Mazda

Component	Factory ECS	Modifications
(1) Carbon canister	Small carbon canister in top of air cleaner for diurnal cycle only.	No change in the diurnal ECS. Added a 4 tube Vega canister for vapors from the carburetor bowl. Bottom of Vega canister capped.
(2) Purge	Crankcase	PCV line used for the purge for Vega canister.
(3) Carburetor	Bowls vent to air cleaner.	Each bowl individually vented to the Vega canister.
(4) Air cleaner	-	No change.
(5) Other	-	A fan was installed to ventilate underhood during hot soak.

Comments:

This vehicle utilizes a small carbon canister on the top of the air cleaner for storage of diurnal cycle vapors. No change was made in this part of the original ECS. The (large volume) two bowl carburetor required separate vents with minimum resistance from each side to transfer vapors into the canister. Even then, an underhood fan was used to cool the carburetor bowl to retard the rate of hydrocarbon vapor release. Without the fan, hydrocarbon vapors from the balance tubes and for drippage in carburetor throat caused the SHED level to exceed the 2 gram level.

For additional details, see Appendix V, and Figures 18, 19, 20, and 21.

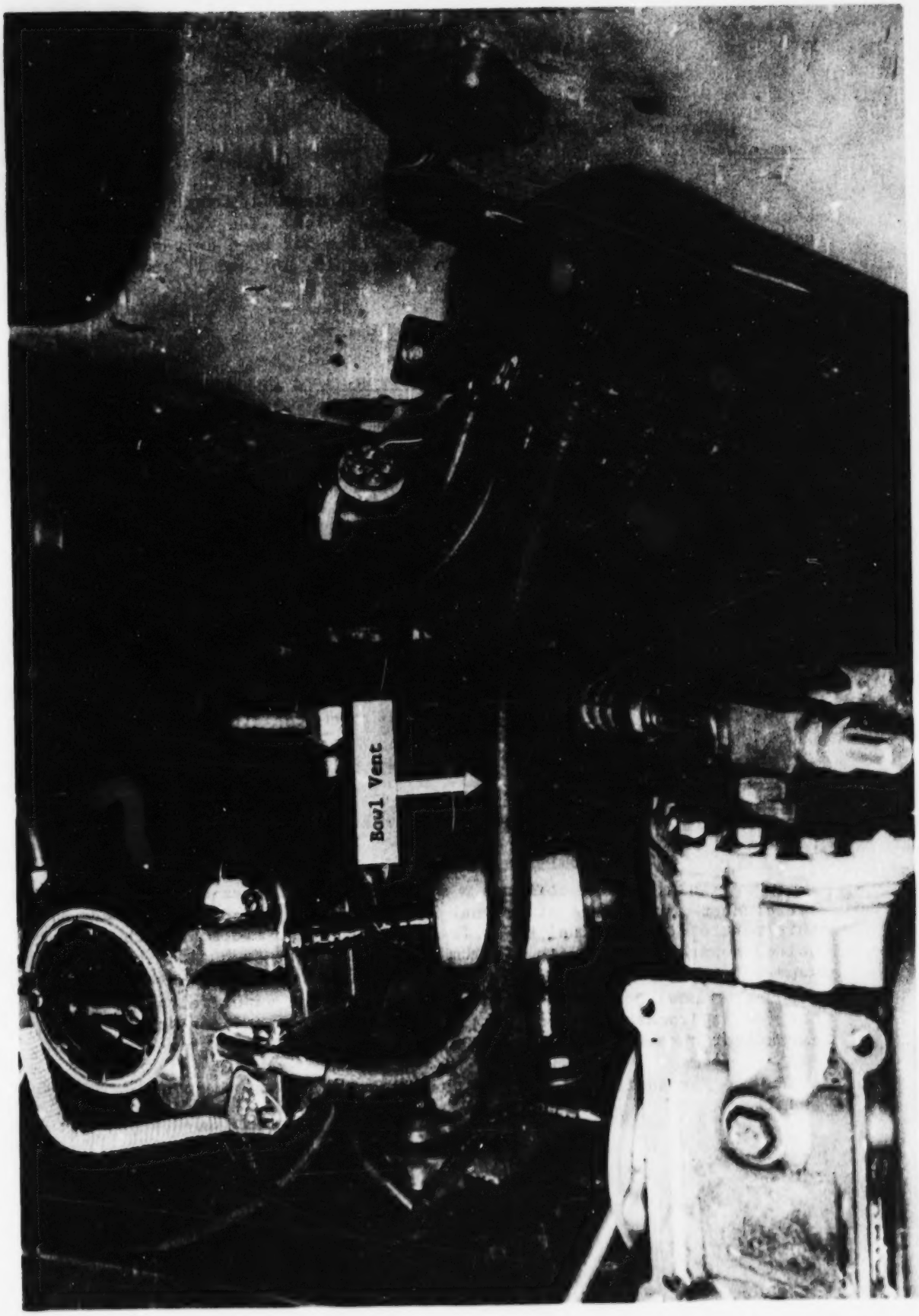


FIGURE 16 CARBURETOR MODIFICATION AND CARBON CANISTER FOR THE HORNET

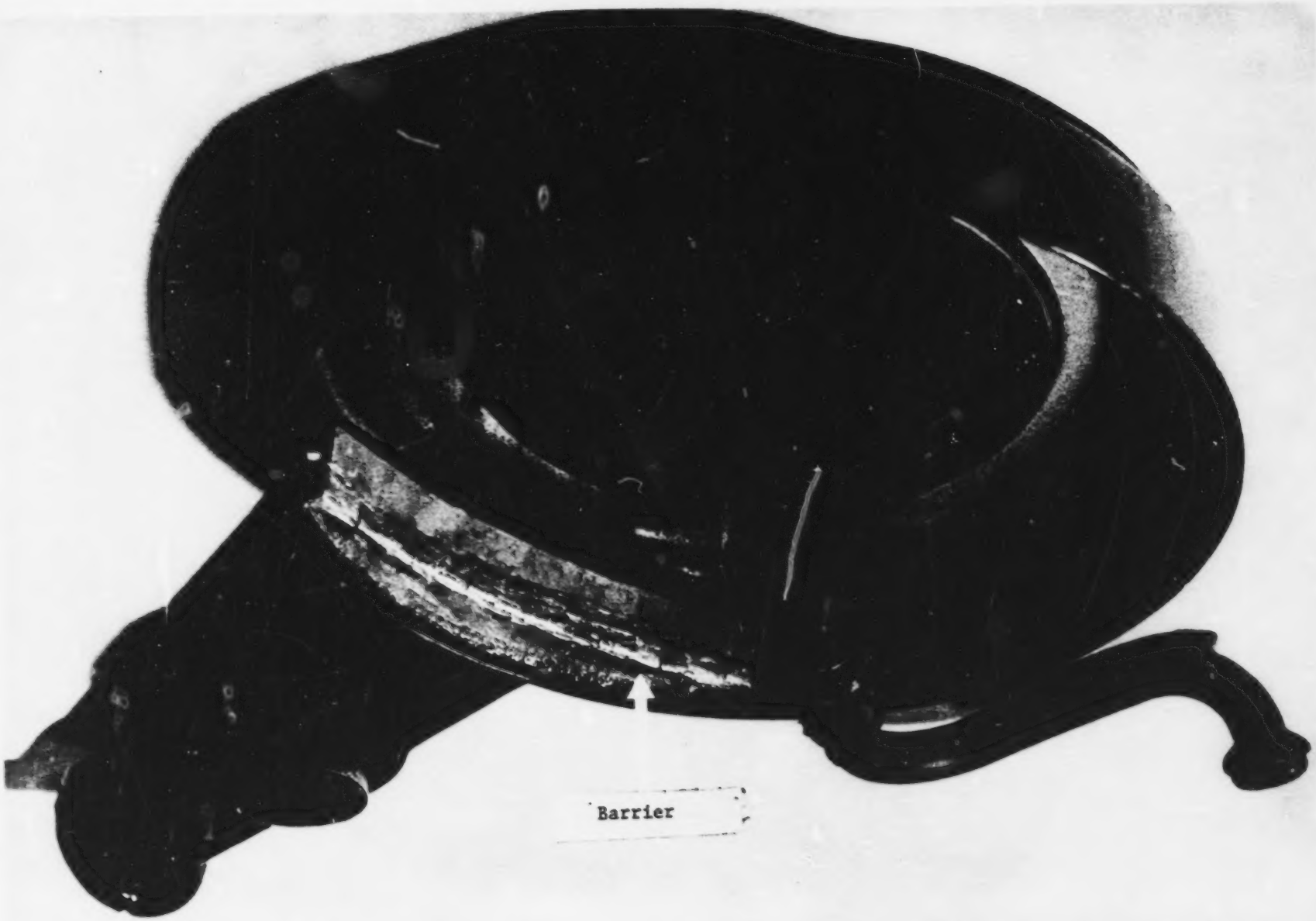


FIGURE 17 BARRIER AT THE BASE OF THE SNORKEL OF THE HORNET AIR CLEANER

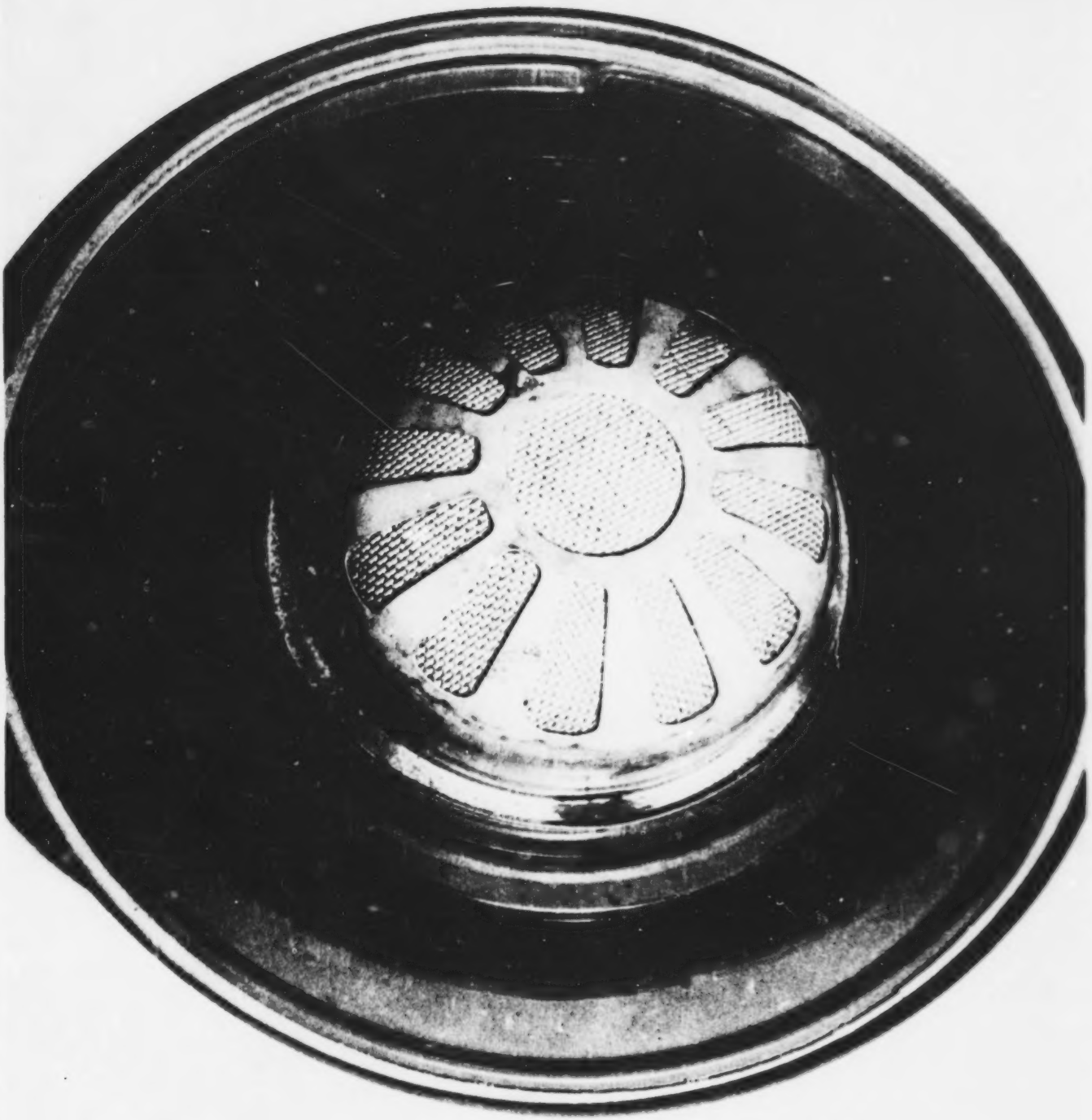


FIGURE 13 CARBON CANISTER IN TOP OF THE AIR CLEANER ON THE MAZDA

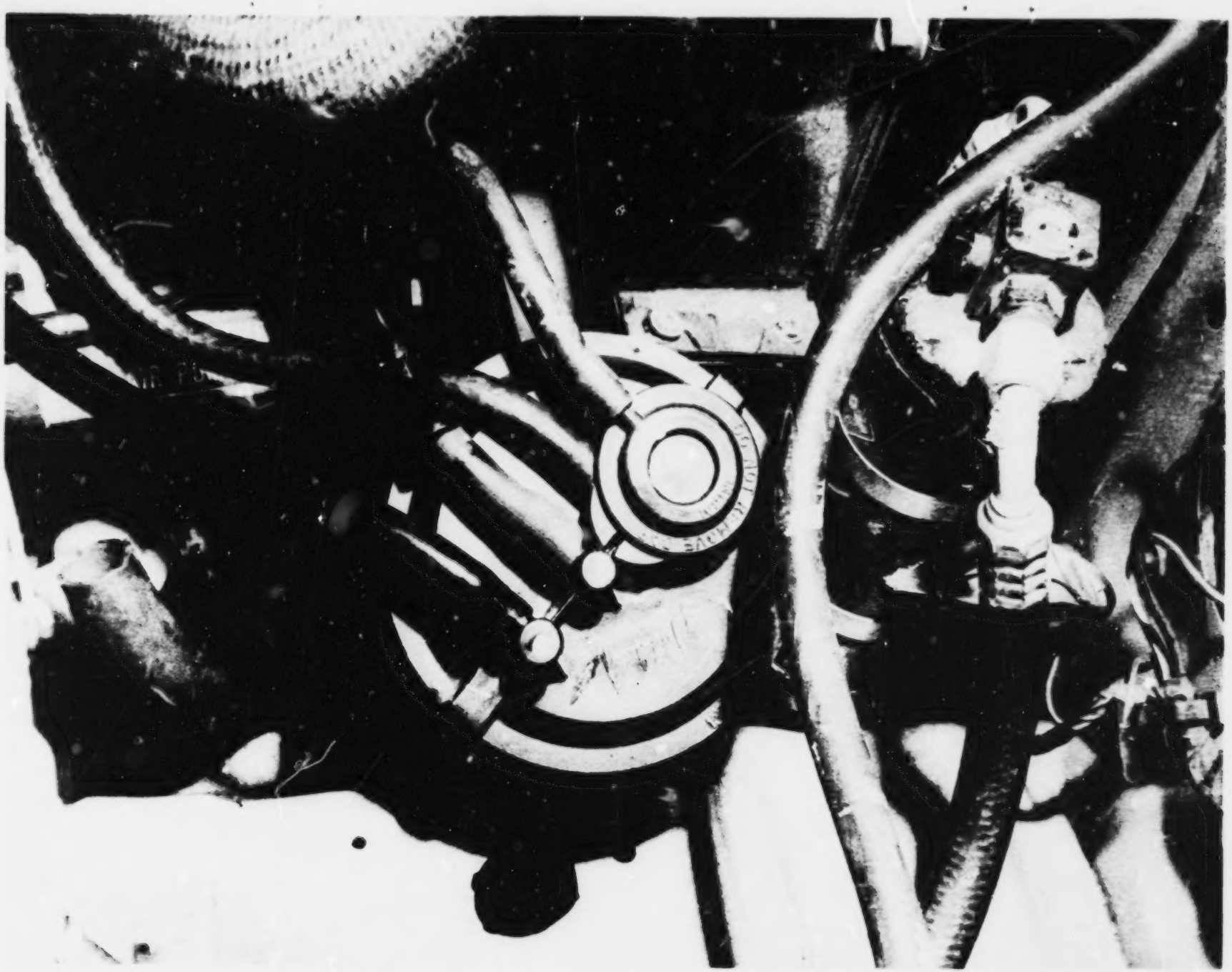


FIGURE 19 CARBON CANISTER USED ON THE MAZDA

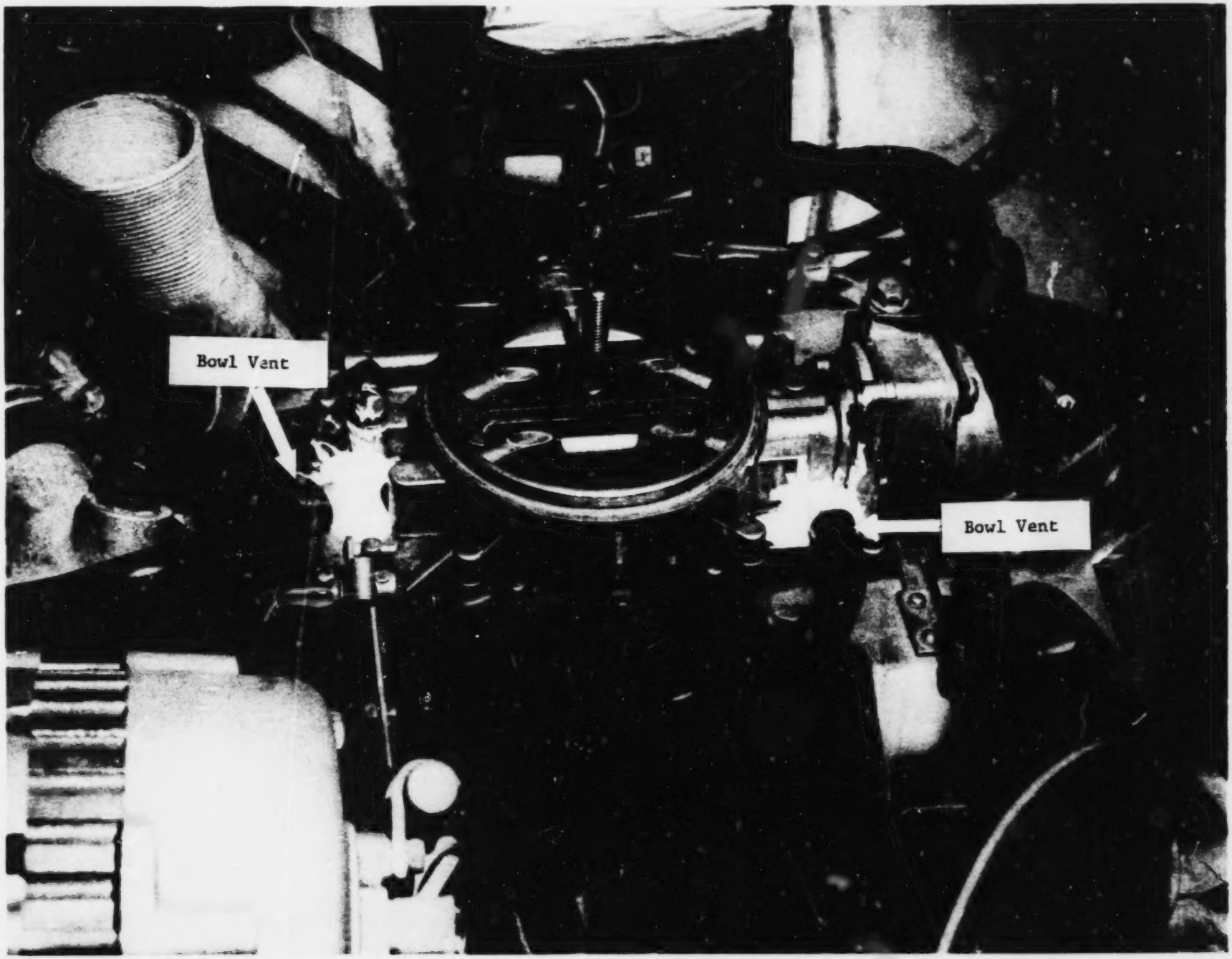


FIGURE 20 CARBURETOR MODIFICATIONS FOR THE MAZDA

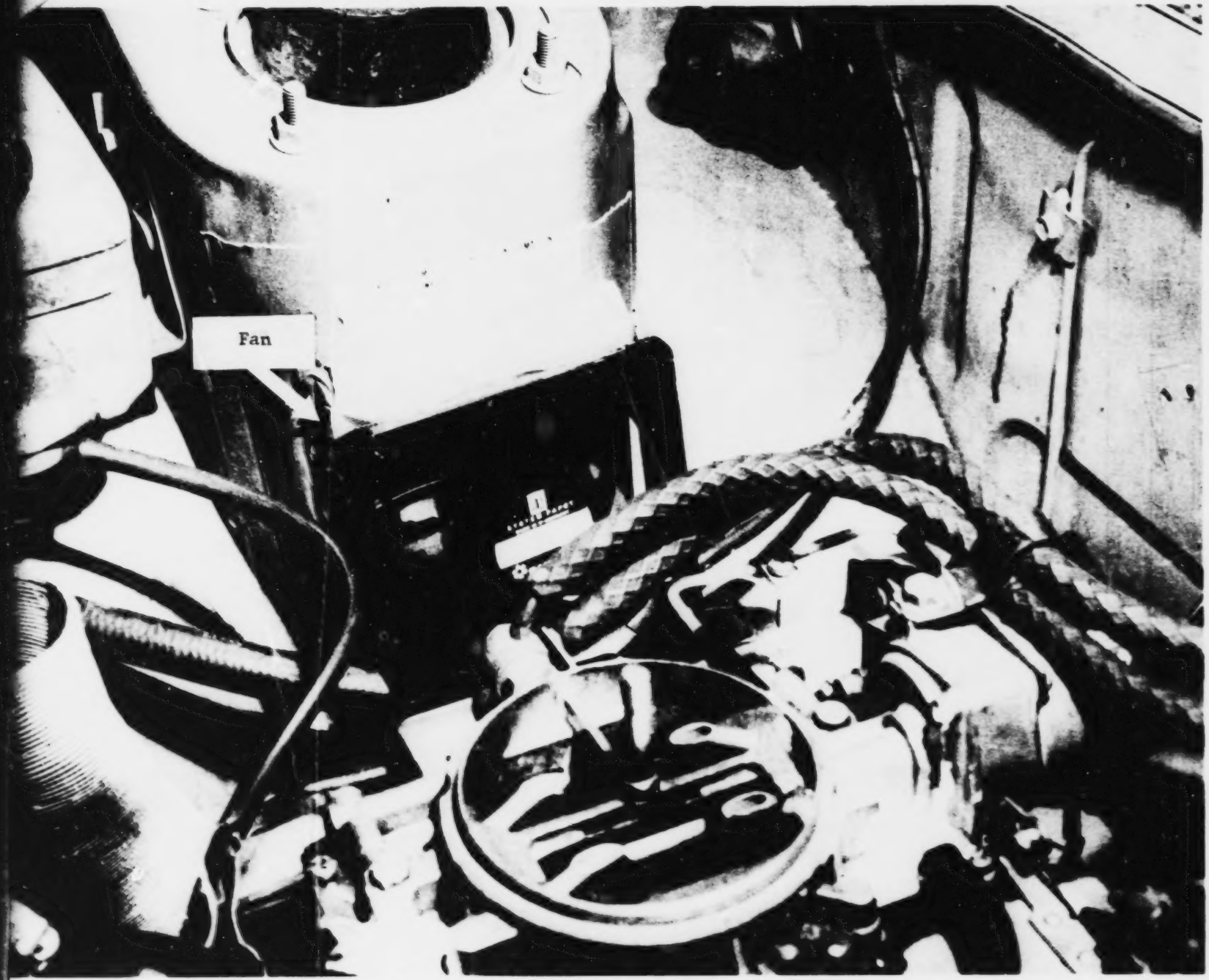


FIGURE 21 FAN FOR UNDERHOOD VENTILATION ON MAZDA

Table XVII

Modifications for Vehicle No. 17 - Volvo

Component	Factory ECS	Modification
(1) Carbon canister	Small one tube carbon canister.	Changed to a 2 tube AMC canister.
(2) Purge	Intake manifold	No change.
(3) Carburetor	None - fuel injected.	-
(4) Air cleaner	No leaks.	No change.
(5) Fuel tank	Uses an equalizing valve regulating tank pressure to about 1.0 psi (6.9 kPa).	Pressure of equalizing valve modified to 0.5 psi (3.5 kPa). Baffle installed between fuel tank and muffler.

Comments:

The factory canister was ineffective. (It did not change weight during the test period.) Consequently the AMC canister was utilized. The high fuel tank pressure resulting from the original equalizing valve pressure of 1.0 psig caused hydrocarbon vapors to escape through the gas cap and other fittings. The lower pressure for the modified equalizing valve corrected this hydrocarbon loss.

For additional details, see Appendix V and Figures 22 and 23.

C. Emissions from Modified Vehicles

1. Evaporative Emissions

a. Total Evaporative Emissions

SHED test results for the six modified vehicles averaged 1.5 grams with a high of 1.9 and a low of 1.1 grams. These data are an average of two or more tests and include vehicle background. Individual car data are compared with unmodified results as follows:

FIGURE 22 CARBON CANISTER INSTALLATION FOR VOLVO

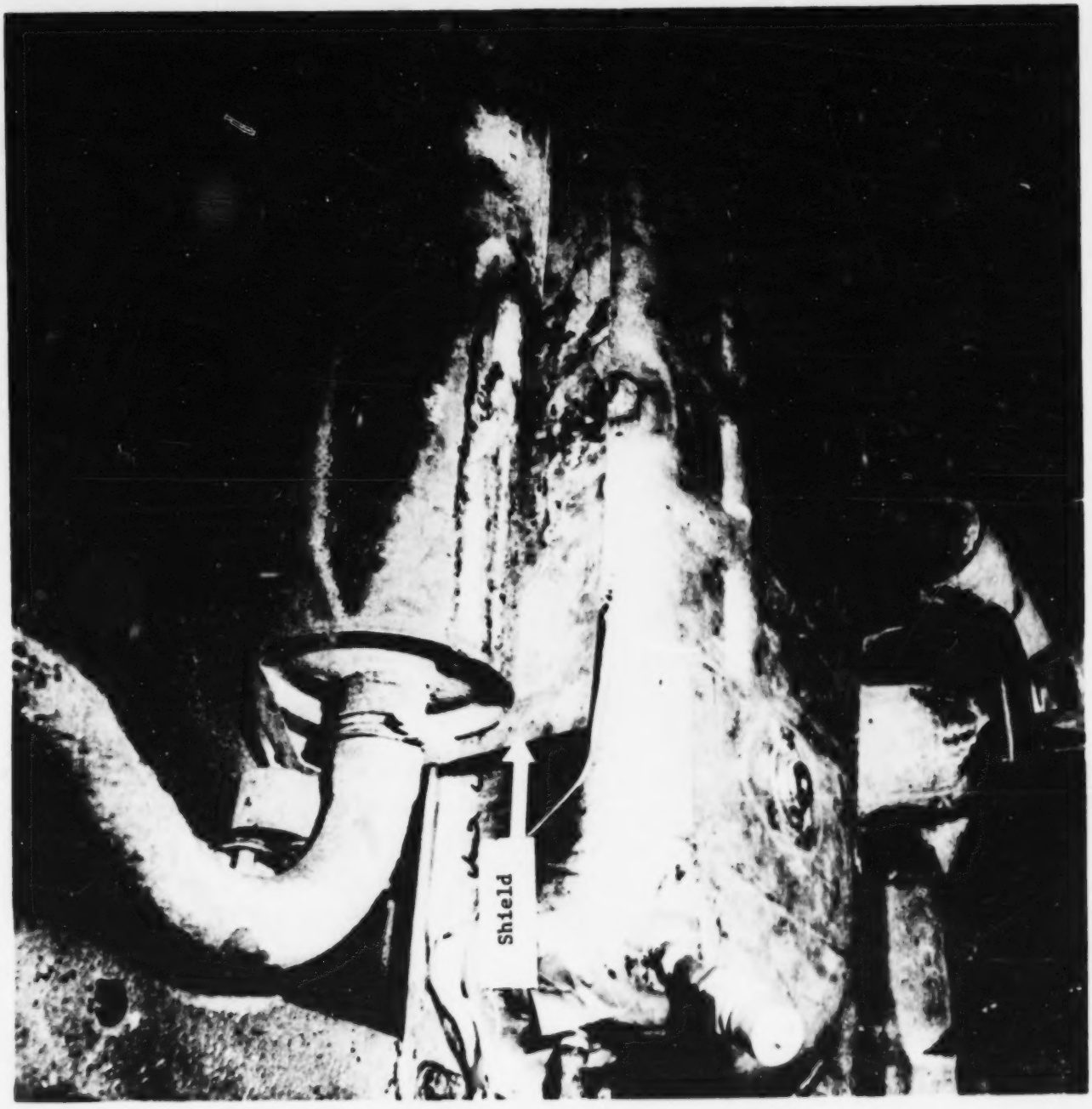


FIGURE 23 HEAT SHIELD FOR VOLVO FUEL TANK

Table XVIII

Comparison of "Modified" Emissions and "As Received"

Car No.	Make	Year	Total Grams/SHED Test	
			Modified	As Received
1	LTD	75	1.2	6.7
2	Pontiac	75	1.9	7.5
11	Hornet	74	1.2	10.8
15	Mazda	74	1.5	12.2
17	Volvo	74	1.1	7.7
21	Chrysler	75	1.9	14.0

b. Adjustment for Background Levels

The SHED data above were adjusted for background levels using the background data from the initial SHED test work (Table V) with the exception of Car No. 15. Because of the exceptionally high initial background for this vehicle, it was retested. Background adjustments are shown below:

Table XIX

Total Evaporative Losses Adjusted for Background

Car No.	Make	Before Background Adj., Grams	Background, Grams	After Background Adj., Grams
1	LTD	1.2	-	1.2
2	Pontiac	1.9	-	1.9
11	Hornet	1.2	0.1	1.1
15	Mazda	1.5	0.5	1.0
17	Volvo	1.1	0.2	0.9
21	Chrysler	1.9	0.1	1.8

c. Loss by Mode of Operation

The hot soak and diurnal losses for the modified vehicles are shown in the following table.

Table XX

Diurnal and Hot Soak Data

Car No.	Make	Year	SHED, Grams[1]		
			Total	Diurnal	Hot Soak
1	LTD	75	1.2	0.2	1.0
2	Pontiac	75	1.9	1.2	0.7
11	Hornet	74	1.2	0.3	0.9
15	Mazda	74	1.5	0.6	0.9
17	Volvo	74	1.1	0.7	0.4
21	Chrysler	75	1.9	0.6	1.3

(1) Not adjusted for background.

2. Exhaust Emissions

Modifying the ECS caused some changes in the exhaust emissions of the modified vehicles. The greatest change was in the CO levels. The CO level: (1) decreased for the three vehicles with catalyst beds, (2) increased for one vehicle, and (3) did not change for the remaining two vehicles. Only minor changes in the HC and NO_x levels were noticed. A summary of the exhaust emissions data is shown below:

Table XXI

Exhaust Emissions - Modified Vs. As Received

Car No.	Make	Year	ECS Modified	Exhaust Emissions, Grams/Mile[1]		
				CO	HC	NO_x
1	LTD	75	Yes	4.44	0.52	1.87
			No	6.75	0.54	1.62
2	Pontiac	75	Yes	4.05	0.68	1.36
			No	6.95	0.80	1.31
21	Chrysler	75	Yes	13.3	1.10	1.83
			No	23.2	2.32	1.98
11	Hornet	74	Yes	26.9	1.51	1.13
			No	24.5	1.50	1.24
15	Mazda	74	Yes	9.90	1.82	0.65
			No	11.7	2.11	0.88
17	Volvo	74	Yes	22.6	1.24	1.58
			No	13.3	0.91	2.15

(1) Average of two or more tests.

This program was not of sufficient duration to identify the factors causing the above changes. The changes might be due to:

Alteration in the Induction System

For each car, the canister was changed as the vehicle was modified. This could change the purge rate and, in turn, may affect manifold vacuum. (There were no noticeable effects on driveability during the Federal Procedure.) In the case of Car No. 1, 11, and 15, major changes were made in the ECS.

Increase in ECS Hydrocarbon Levels

The improved ECS in each case requires the engine to handle a greater amount of hydrocarbon from the storage systems. This might affect the A/F ratio and subsequently exhaust emissions.

D. Conclusions from Vehicle Modification Work

The experience gained in modifying ECS systems can be summarized as follows:

1. Larger carbon canisters (activated carbon) were required in many cases.

2. Induction system containment of carburetor hot soak emissions does not appear to be an adequate control for carburetor emissions.

3. All air cleaner and carburetor leak sources must be eliminated.

4. Air cleaner and air cleaner snorkel purge systems are inadequate purge systems for a stricter control of evaporative emissions.

5. Under very severe underhood temperature conditions, it may be necessary to minimize heat input to the carburetor by mechanical means such as by an underhood fan.

E. Estimated Costs, Effectiveness, and Durability of Modifications

We have estimated the costs for each of the modifications shown in Table IX. Cost data are outlined in Table XXII. The basis for the cost data has been estimated as manufacturer's cost times two. In the case of carburetor modifications, the indicated figures were obtained from Exxon's automotive consultant who is highly knowledgeable in this field and has been associated with a major carburetor manufacturing company before retirement. The cost of the fan was obtained from an automotive manufacturer. In the case of carbon canisters, the cost information was obtained from a major manufacturer of these devices.

TABLE XXII

ESTIMATED COSTS, EFFECTIVENESS, AND DURABILITY OF MODIFICATIONS

Modification	Estimated Costs[1] $	Estimated Potential Effectiveness	Anticipated Durability
A. Air Cleaner Overflow:			
Control No. 1 - Bowl vent to canister	0.50[1]	High	Good
Control No. 2 - Ventilate with fan	17.00[2]	High	Good
Control No. 3 - Barrier at base of snorkel	0.20	High	Good
Control No. 4 - Smaller bowl	0.20[1]	High	Good
Control No. 5 - Ventilate with louvers	0.0	Low	Good
B. Canister Overflow:			
Control No. 6 - Increase carbon bed 50%	4.00[3]	High	Good
Control No. 7 - Increase current purge	0.60[1][4]	High	Good
Control No. 8 - Close canister bottom	0.20[1]	High	Good
Control No. 9 - Control 2	17.00[2]	High	Good
Control No. 10 - Control 3	0.20[1]	High	Good
Control No. 11 - Heat purge air	0.50[1]	Fair	Good
Control No. 12 - Minimize heat input to fuel tank	1.00+[1]	High	Good
Control No. 13 - Minimize tank vapor space	15.0[5]	Poor	Poor
C. Carburetor Leaks:			
Control No. 14 - Seal shafts with boot	0.30[1]	High	Good
Control No. 15 - Use diaphragm accel. pump	1.00[1]	High	Good

(1) Basis for estimated cost in case of carburetor and ECS modifications is two times the cost to manufacturer.
(2) Vehicle retail price estimate from an automotive manufacturer. Capacity - 100 CFM (47.2 dm^3/s).
(3) Cost increment based on cost information from a charcoal canister manufacturer.
(4) In cases where an existing canister is replaced by the Vega canister, cost is $1.00.
(5) Not a firm estimate.

The estimated costs for the actual modifications for each of the six vehicles are shown below. The costs vary from a low of $2.00 to a high of $25.20. The two vehicles with underhood fans, the Pontiac and Mazda, have cost figures substantially above the other vehicles. Following these tests, the Pontiac was equipped with a Vega canister to replace the fan. Use of this canister also resulted in emissions less than 2 grams/test. The cost figures shown in Table XXII were used in estimating the modification price for each vehicle. Details for the modification costs for each vehicle are given in Appendix VI.

Table XXIII

Estimated Costs of Modifications

Car No.	Make	Year	Modification Costs, $
1	LTD	75	2.00
2	Pontiac	75	18.30 or 2.30(1)
11	Hornet	74	2.50
15	Mazda	74	25.20
17	Volvo	74	2.00
21	Chrysler	75	5.70(2)

(1) $18.30 uses an underhood fan. $2.30 system uses a Vega canister which eliminates the fan.
(2) Assumes one canister of larger than current capacity would be used in lieu of two units as per this work.

The potential effectiveness and durability of each of the modifications is shown in Table XXII. In our opinion, most modifications are expected to be effective with a good durability rating. The basis for the ratings include personal judgment and field experience with modifications of similar nature. No longevity runs were performed as part of this program.

VI. EMISSION LEVELS OF MODIFIED VEHICLES UNDER SEVERE TEST CONDITIONS

The performance of two of the modified vehicles has been evaluated under the severe test conditions of (1) use of a fuel of higher RVP than Indolene, and (2) raising the maximum temperature of the diurnal cycle. For this work, Vehicles No. 1 and 2 were selected. Vehicle No. 2 was equipped with the underhood fan for these tests. Test conditions were standard SHED with the exception of the higher volatility fuel in one case and the higher temperature range for the diurnal in the second case. For the high volatility fuel, butane was added to Indolene to raise its RVP from 62.1 to 71.7 kPa (9.0 to 10.4 psi). Inspections for this fuel are given in Appendix II. Standard Indolene was used for the high temperature diurnal cycle runs. For these, the diurnal range was 15.6 to 35°C (60 to 95°F) in lieu of the standard SHED range of 15.6 to 28.9°C (60 to 84°F).

The results from this work indicate that Vehicle No. 2, the Pontiac, had more reserve storage capacity after modification than the LTD, Vehicle No. 1. The 1.4 psi (9.65 kPa) increase in RVP increased SHED emissions 1.0 gram for the Pontiac and 4.5 grams for the LTD. Extending the diurnal cycle increased SHED losses 2.1 grams for the Pontiac and 3.2 grams for the LTD. Data are summarized below and presented in detail in Appendix VII and in Table XXIV.

Table XXIV

Higher Losses Under Severe Test Conditions

Car No.	Make	Increase Loss, Grams/SHED Test	
		High RVP	High Temp. Diurnal
1	LTD	4.5	3.2
2	Pontiac	1.0	2.1

The more severe test conditions described above did not significantly affect exhaust emissions with these two vehicles, both of which have catalytic reactors to control tailpipe emissions. Exhaust emissions data are included in Appendices No. VII and VIII.

VII. HALOGENATED HYDROCARBONS IN EVAPORATIVE EMISSIONS

A brief analytical study has been carried out to measure the level of halogenated hydrocarbons in the evaporative emissions from leaded fuels. Two halogenated hydrocarbons, ethylene dichloride and ethylene dibromide, are part of the lead scavenger package of most leaded gasolines. The concentration of these scavengers is about 0.1 wt. % of a fuel containing about 3.0 ml/TEL per gallon. The ethylene dichloride is present at twice the concentration level of the ethylene dibromide.

An exploratory analytical procedure was developed to measure the scavenger level in the evaporative emissions of a vehicle. For this, a gas chromatograph equipped with a sensitive microcoulometer detector was used. The source of the evaporative emission was a full size car hot soaking in a SHED for one hour. The fuel was a full boiling range gasoline containing about 3.0 ml/TEL gallon as Motor Mix. The hydrocarbon level in the SHED was 300 ppm C after the hot soak. The concentration of ethylene dichloride in the SHED was 0.128 µg/l. This is about 0.1% of the hydrocarbon value in the SHED. We detected but did not quantify the ethylene dibromide. The boiling point for the ethylene dibromide is much higher than the ethylene dichloride - 131.7°C vs. 83.7°C.

Because of the low level of scavengers in evaporative emissions, it was decided not to conduct additional work in this area at this time.

APPENDIX NO. I-1

SURVEY OF CARS AND LIGHT TRUCKS FOR EVAPORATIVE CONTROL SYSTEMS

F = Full Size
I = Intermediate
C = Compact

Make	Yr.	Model	Displ. Litres	# of Bbls.	Canister				Purge			Fuel Tank		Vapor Return Line?	Type
					2 Tube	3 Tube	4 Tube	Purge Valve?	Line To: PCV	Carb	Air Cl.	Litres	Near Exh. Line?		
Ford	73	I	5.75	4	✓						✓	85.2	N	N	III
	73	F	6.56	2	✓						✓	85.2	N	Y	III
	73	F	7.03	4	✓						✓	85.2	N	Y	III
	74	I	5.75	2	✓						✓	83.3	Y	N	III
	74	F	6.56	2	✓						✓	83.3	N	N	III
	75	I	5.75	2		✓					✓	90.8	N	N	VI
	75	F	6.56	2		✓					✓	90.8	N	N	VI
	75	I	4.95	2	✓						✓	85.2	N	N	III
	74	C	3.33	1	✓					✓		49.2	N	N	I
	73	C	1.60	1	✓						✓	41.6	N	N	III
	74	C	2.29	2	✓						✓	49.2	N	N	III
	75	I	4.10	1	✓						✓	90.8	N	N	III
Mercury	73	F	7.03	4	✓						✓	83.3	N	Y	III
	74	F	7.54	4	✓						✓	83.3	N	Y	III
	74	I	5.75	2	✓						✓	100.3	N	N	III
	75	I	5.75	2	✓						✓	100.3	N	N	III
	75	C	3.33	2	✓					✓		49.2	N	N	I
	73	I	4.95	2	✓						✓	85.2	N	N	III
Lincoln	75	F	7.54	4		✓					✓	100.3	N	Y	VI

APPENDIX NO. I-2

SURVEY OF CARS AND LIGHT TRUCKS FOR EVAPORATIVE CONTROL SYSTEMS

F = Full Size
I = Intermediate
C = Compact

					Canister				Purge			Fuel Tank		Vapor Return	
									Line To:				Near		
Make	Yr.	Model	Displ Litres	# of Bbls.	2 Tube	3 Tube	4 Tube	Purge Valve?	PCV	Carb	Air Cl.	Litres	Exh. Line?	Line?	Type
Plymouth or Dodge	73	I	3.69	1		✓				✓		60.6	N	N	IV
	75	I	3.69	1		✓				✓		60.6	N	N	IV
	75	I	3.69	1	✓					✓		60.6	N	N	I
	74	F	5.21	2	✓					✓		60.6	N	N	I
	74	F	5.90	4	✓					✓		79.5	N	N	I
	73	F	6.56	2		✓				✓		79.5	N	N	IV
	73	F	6.56	4		✓				✓		79.5	N	N	IV
	75	F	7.21	4	✓					✓		79.5	N	N	I
Chrysler	74	F	6.56	4		✓				✓		73.5	N	N	IV
	75	F	7.21	4	✓					✓		98.0	N	N	I
	74	F	7.21	4		✓				✓		98.0	N	N	IV
	73	F	7.21	4		✓				✓		98.0	N	N	IV
AMC	73	C	3.80	1		✓		✓	✓			39.7	N	N	II
	75	I	4.23	1		✓					✓	60.6	N	N	VI
	75	I	4.98	2	✓						✓	94.6	N	N	III
	74	I	5.90	4	✓						✓	92.7	N	N	III
	74	I	4.98	2	✓						✓	64.3	N	N	III

APPENDIX NO. I-3

SURVEY OF CARS AND LIGHT TRUCKS FOR EVAPORATIVE CONTROL SYSTEMS

F = Full Size
I = Intermediate
C = Compact

Make	Yr.	Model	Displ. Litres	# of Bbls.	Canister				Purge			Fuel Tank		Vapor Return Line?	Type
					2 Tube	3 Tube	4 Tube	Purge Valve?	Line To: PCV	Carb	Air Cl.	Litres	Near Exh. Line?		
Chevrolet	75	C	4.10	1		✓		Y	✓			79.5	Y	N	II
	74	I	4.10	1		✓		Y	✓			79.5	Y	N	II
	73	I	4.10	1		✓		Y	✓			83.3	N	N	II
	75	F	5.74	2	✓			N		✓		83.3	N	N	I
	75	F	5.74	4	✓			N		✓		83.3	N	Y	I
	74	F	6.56	4	✓			N		✓		98.4	N	Y	I
	73	F	5.74	4		✓		N		✓		98.4	N	N	IV
	73	F	6.56	2		✓		Y		✓		98.4	N	Y	II
	74	F	5.74	2	✓			N		✓		83.3	N	N	I
Vega	75	C	2.29	2			✓	Y	✓			60.6	Y	Y	IV
	73	C	2.29	1		✓		Y	✓			41.6	Y	Y	II
Monza	75	C	2.29	2	✓			N		✓		70.0	Y	N	I
	75	C	2.29	2	✓			N		✓		70.0	Y	N	I
Pontiac	74	F	4.10	1	✓			N		✓		95	N	N	I
	73	I	5.74	2	✓			N		✓		95	N	N	I
	73	F	6.56	2	✓			N		✓		95	Y	Y	I
	73	F	6.56	4	✓			N		✓		95	N	Y	I
	75	F	6.56	4	✓					✓		95	N	Y	I
	75	F	6.56	4	✓					✓		95	N	Y	I
	75	F	6.56	2		✓				✓		95	N	Y	IV

APPENDIX NO. I-4

SURVEY OF CARS AND LIGHT TRUCKS FOR EVAPORATIVE CONTROL SYSTEMS

F = Full Size
I = Intermediate
C = Compact

Make	Yr.	Model	Displ. Litres	# of Bbls.	2 Tube	3 Tube	4 Tube	Purge Valve?	Purge Line To: PCV	Carb	Air Cl.	Fuel Tank Litres	Near Exh. Line?	Vapor Return Line?	Type
Cadillac	73	F	7.74	4	✓				✓			102	N	N	I
	75	F	8.20	4		✓				✓		104	N	Y	IV
Olds	73	I	5.71	4	✓					✓		83.3	N	N	I
	73	F	7.46	4	✓					✓		79.5	N	Y	I
	74	I	4.10	1		✓		✓	✓			79.5	Y	N	II
	75	I	5.74	4		✓				✓		83.3	N	N	IV
	75	F	7.46	4		✓				✓		98.4	N	Y	IV
Buick	74	F	5.74	2	✓						✓	83.3	N	Y	III
	75	I	4.29	2	✓					✓		91.0	N	Y	I
	75	I	5.74	4	✓					✓		98.4	N	Y	I
	73	F	7.46	4	✓					✓		98.4	N	Y	I
	73	I	5.74	2	✓					✓		83.3	N	Y	I
	73	F	5.74	4	✓						✓	98.4	N	Y	III
	75	F	5.74	4		✓		✓	✓			98.4	N	Y	II
	75	I	3.80	1	✓					✓		98.4	N	N	I

APPENDIX NO. I-5

SURVEY OF CARS AND LIGHT TRUCKS FOR EVAPORATIVE EMISSION CONTROLS

Make	Yr.	Model	Displ. Litres	# of Bbls.	2 Tube	3 Tube	4 Tube	Purge Valve?	Purge Line To: PCV	Purge Line To: Carb	Purge Line To: Air Cl.	Fuel Tank Litres	Fuel Tank Near Exh. Line?	Vapor Return Line?	Type
VW	73	Bug	1.5	1	✓						✓	40.1	N	N	---
	75	Bug	1.6	1	✓						✓	40.1	N	N	---
	75	Rab.	1.5	1	✓						✓		N	N	---
Fiat	75	1800	1.8	1		✓				✓			N	Y	-
	75	1300	1.3	1		✓				✓			N	Y	-
Opel	74	Manta	1.9	1		✓				✓		45	Y	N	-
Mitsubishi	75	Colt	2.0	2	✓						✓		N	Y	III
Peugeot	73	504	1.97	2	✓					✓			N	N	I
Volvo	74	I	1.98	F.I.	✓					✓		59.8	N	N	I
Datsun	74	210	2.1	2	Crankcase Storage				✓			43.9	N	N	VIII
British Leyland	75	MG	1.8	2	✓				✓			53	N	N	II
Toyota	74		2.6	2	✓				✓			45	Y	N	II
	75		2.6	2	✓				✓			45	Y	N	II
Audi	74		1.5	2	✓						✓	45			III
	75		1.5	2	✓						✓	45			III
BMW	74		2.0	2	✓					✓		72			I
Honda	75		1.5	2	✓					✓		41.7	N	N	I

Mazda - A condensor tank in trunk collects and condenses tank vapors. Excess vapor from condensor tank goes to PCV valve then to atmosphere. Carburetor vapors stored in induction system.

Mercedes-Benz - A compensating tank and a combination valve system condense vapors and store excess in the crankcase.

APPENDIX NO. I-6

SURVEY OF CARS AND LIGHT TRUCKS FOR EVAPORATIVE EMISSION CONTROLS

Make	Yr.	Model	Displ. Litres	# of Bbls.	2 Tube	3 Tube	4 Tube	Purge Valve?	Purge Line To: PCV	Purge Line To: Carb	Purge Line To: Air Cl.	Fuel Tank Litres	Fuel Tank Near Exh. Line?	Vapor Return Line?	Type
Ford	75	F250	4.92	1	✓						✓	72.5	N	N	III
	74	F100	3.93	1	✓						✓	72.5	N	N	III
International	73	Travall	5.65			✓				✓		79.5	N	N	V
	74	Travall	6.56			✓				✓		79.5	N	N	V
Dodge	75	Van				✓				✓		87.1	N	N	V

Chevrolet, Dodge, Plymouth and Ford light trucks same as cars.

APPENDIX II

VOLATILITY INSPECTIONS FOR TEST FUELS

Inspections	Indolene		High RVP[1] Fuel
	Unmodified Cars	Modified Cars	
Reid Vapor Pressure	62.1 kPa (9.0 psi)	62.1 kPa (9.0 psi)	71.7 kPa (10.4 psi)
Distillation[2], Temp. for ind. D + L:			
IBP	36.1°C (97°F)	33.3°C (92°F)	31.1°C (88°F)
5	48.9°C (120°F)	46.7°C (116°F)	43.3°C (110°F)
10	55.6°C (132°F)	54.4°C (130°F)	52.2°C (126°F)
15	62.8°C (145°F)	62.8°C (145°F)	61.1°C (142°F)
20	69.4°C (157°F)	70.6°C (159°F)	70.0°C (158°F)
30	82.2°C (180°F)	86.1°C (187°F)	86.1°C (187°F)
40	93.9°C (201°F)	97.8°C (208°F)	97.8°C (208°F)
50	105.0°C (221°F)	105.6°C (222°F)	105.6°C (222°F)
90	158.9°C (318°F)	161.7°C (323°F)	161.7°C (323°F)
FBP	211.7°C (413°F)	206.1°C (403°F)	206.1°C (403°F)

(1) This fuel prepared for the wok presented in part VI of this report.
(2) ASTM Designation D-86.

APPENDIX III

PROCEDURE FOR QUANTIFYING EVAPORATIVE LOSSES

The procedure for quantifying losses involves collecting the vapors and adsorbing them on activated carbon. This is carried out in such a manner as to minimize the disturbance of the flow of hydrocarbon from the leak source. Vapors are drawn into the collector at a carefully controlled flow rate. They pass through a dryer and then into the carbon bed. Non-adsorbed sample is returned to the shed. Provision is made to check the sample leaving the carbon bed for the presence of non-adsorbed vapors. A sketch of the equipment is shown i Figure I.

The flow rate in the collector is critical. Too high a rate will lead to excessive losses from the leak source. Too low a rate will allow vapors to escape into the shed. The range of operable rates is 2.5 to 25 cfh. (71 to 710 L/h). The low rate is effective for 1.0 g/hr or less and the higher rate for 10+ g/hr. The collector flow rate is matched to the source loss rate. If the F.I.D. trace for a hot soak shows a high loss rate for the first fifteen minutes of a run followed by a low loss rate the remainder of the soak, the collector flow rate is set high for 15 minutes and then lowered.

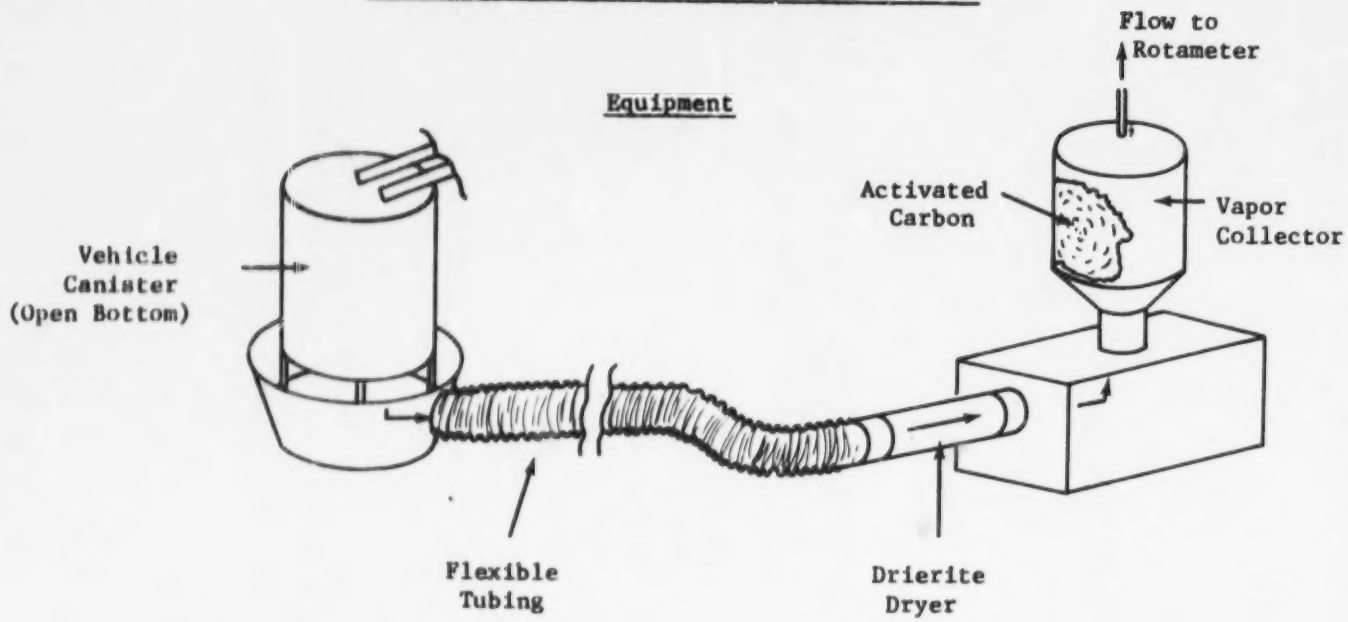
For most vehicles, the collection equipment can be installed prior to the run so as to minimize the length of time the hood is open during a run. Small leaks in the air cleaner are sealed before the test.

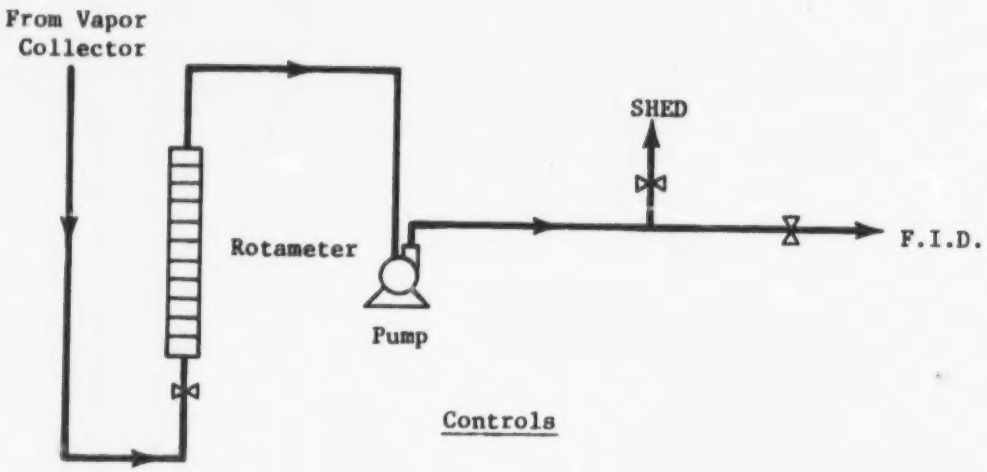
The carbon for the collector is activated, non-polar carbon of 10-20 mesh. It is dried prior to use. Volume of carbon is varied with the amount of vapor to be collected.

APPENDIX III

FIGURE I

EQUIPMENT FOR QUANTIFYING EVAPORATIVE LEAKS





Controls

APPENDIX IV

TABLE I

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Ford LTD
Year: 75
No.: 1
Displ. cu. in./Litre: 351/5.75
No. Cyl.: 8
No. Venturis: 2

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
1) SHED #2	2.66	--	--	--	3.56	--	--	--	6.22	0.74(1)	1.39(1)	
2) Quantifying #1	0.12	--	3.06	--	0.48	0.0	2.94	--	6.60			
3) Quantifying #2	0.08	--	1.27(2)	--	0.48	0.0	0.92(2)	--	2.75(2)			
4) Quantifying #3	0.18	--	4.01	--	1.50	0.82	3.42	--	9.93(3)			
5) SHED #3	4.21	--	--	--	2.90	--	--	--	7.11			

(1) High background due to fuel contamination on floor carpet. A fuel can had been placed on the floor of the vehicle as an auxiliary fuel tank after SHED Test #3. Spillage from this can occurred some time prior to the background test which was run after the SHED testing.

(2) Heated air tube from exhaust manifold inadvertently closed off at air cleaner snorkel during this run. Postulated that the increase in pressure drop in the air cleaner purged the canister to a greater extent than for a normal run.

(3) Flow rates to collector hydrocarbon beds too high for this run. This tends to pull vapors from air cleaner and canister.

APPENDIX IV

TABLE II

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Pontiac
Year: 75
No.: 2
Displ. cu. in./Litre: 400/6.56

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.41	--	--	--	6.83	--	--	--	7.24	0.50(1)	0.84(1)	
(2) SHED #2	0.37	--	--	--	7.40	--	--	--	7.77			
(3) Quantifying #1	0.46	--	0.20	--	1.77(2)	3.62	--(3)	1.77(2)	6.05			
(4) Quantifying #2	0.41	--	0.45	--	1.95(2)	4.60	0.23	1.95(2)	7.64			
(5) Quantifying #3	0.20	0.22	0.19	--	1.61(2)	4.80	0.35	1.61(2)	7.37			

(1) Results from the background tests very high. A fuel can had been used in the vehicle after the SHED testing. Spillage from this can contributed to high background test which was run after the SHED testing.

(2) Carburetor leak around accelerator pump shaft. Vapors escaped to the SHED because the leak is unaccessible from a quantifying standpoint.

(3) Collector for hydrocarbon inadvertently omitted.

APPENDIX IV

TABLE III

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Chrysler NYer
Year: 75
No.: 3
Displ. cu. in./Litre: 440/7.21
No. Cyl.: 8
No. Venturis: 4

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) Quantifying #1	0.08	0.0	6.46	--	2.10(1)	0.0(2)	0.0(2)	2.10(1)	8.64(2)	0.03	0.13	
(2) Quantifying #2	0.32	0.0	3.50	--	1.34(1)	0.32(2)	0.0(2)	1.34(1)	5.48(2)			
(3) Quantifying #3	0.17	0.0	3.88	--	2.01(1)	0.0(2)	0.0(2)	2.01(1)	6.06(2)			
(4) SHED #2	7.30	--	--	--	10.63	--	--	--	17.93			
(5) SHED #3	8.63	--	--	--	7.76	--	--	--	16.39			

(1) Carburetor leak - vapors escape from around carburetor accelerator pump shaft as it passes through the air horn. Vapors escape to the shed because the leak is unaccessible from a quantifying standpoint.

(2) Carburetor bowl maximum temperature during the hot soak is 15 to 20°F (-9.4 to -6.7°C) lower for quantifying runs than regular SHED tests. This is because hood must be raised to attach hydrocarbon collection equipment when quantifying; consequently, less hydrocarbon is lost from the carburetor bowl.

APPENDIX IV

TABLE IV

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Pinto
Year: 74
No.: 4
Displ. cu. in./Litre: 122/2.0
No. Cyl.: 4
No. Venturis: 2

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	2.31	--	--	--	4.62	--	--	--	6.93	0.0	0.16	
(2) SHED #2	1.50	--	--	--	3.95	--	--	--	5.45			
(3) Quantifying #1	0.16	0.0	0.50	--	0.34	0.0(1)	0.0(1)	--	1.0 (1)			
(4) Quantifying #2	0.33	0.0	0.0	--	0.32	0.0(1)	0.0(1)	--	0.65(1)			
(5) SHED #3	1.82	--	--	--	4.39	--	--	--	6.21			

(1) Carburetor bowl maximum temperatures are 8 to 12°F (-13.3 to -11.1°C) lower for quantifying runs than for SHED tests. This is due to heat loss from engine compartment when hood is raised to attach collection equipment for quantifying runs.

APPENDIX IV

TABLE V

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Nova
Year: 74
No.: 5
Displ. cu. in./Litre: 250/4.1
No. Cyl.: 6
No. Venturis: 1

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.39	-	-	-	15.10	-	-	-	15.49	0.0	0.11	(1)
(2) SHED #2	0.58	-	-	-	11.40	-	-	-	11.98			
(3) Quantifying #1	0.15	0.43	0.32	-	6.95(2)	0.71	0.13	6.95(2)	8.67(3)			(2)
New Carburetor Installed												
(4) SHED #3	0.28	-	-	-	10.04	-	-	-	10.32			
(5) Quantifying #2	0.25	-	0.56	-	5.96(2)	1.11	0.0	5.96(2)	7.88(4)			(2)
(6) Quantifying #3	0.28	-	2.20	-	5.60(2)	5.81(4)	1.82	5.60(2)	15.71(4)			
(7) SHED #4	0.25	-	-	-	11.35	-	-	-	11.60			

(1) Carburetor to intake manifold bolts tightened after this run.

(2) Carburetor leaks - the carburetor bowl is vented to the atmosphere upon slight pressure increase in the bowl. Other leaks occurred around the accelerator pump shaft. Unable to quantify carburetor leaks consequently, vapors enter shed.

(3) Hot soak losses lower on quantifying runs 1 and 2 than SHED tests because of lower maximum carburetor bowl temperatures. Raising the hood to attach the vapor collection equipment lowered bowl temperature 20°F (-6.7°C).

(4) For this run, vapors from the external vent were collected along with vapors from air cleaner snorkel. The collecting system pulled HC from the bowl due to too high a flow rate.

APPENDIX IV

TABLE VI

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Chevrolet Impala
Year: 74
No.: 6
Displ. cu. in./Litre: 350/5.74
No. Cyl.: 8
No. Venturis: 2

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.28	-	-	-	4.69	-	-	-	4.97	(1)	(1)	
(2) SHED #2	0.82	-	-	-	4.09	-	-	-	4.91			
(3) Quantifying #1	0.11	-	2.97(2)	-	0.56	7.36(2)	1.71(2)	-	12.71(2)			
(4) Quantifying #2	0.21	-	2.80(2)	-	0.52	7.70(2)	1.61(2)	-	12.84(2)			
(5) SHED #3	0.41	-	-	-	5.56	-	-	-	5.97			

(1) Background tests for this car were extremely high because of fuel spillage on carpet floor. A fuel can had been used as an auxiliary fuel tank after SHED Test #3. Background tests (3+ grams hot and cold) were run after SHED testing.

(2) Collection system pulled vapors from the canister and air cleaner snorkel during the quantifying runs due to too high a flow rate.

APPENDIX IV

TABLE VII

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Plymouth Duster
Year: 74
No.: 7
Displ. cu. in./Litre: 225/3.69
No. Cyl.: 6
No. Venturis: 1

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.50	-	-	-	0.73	-	-	-	1.23	0.66(1)	0.73(1)	
(2) SHED #2	0.44	-	-	-	1.32	-	-	-	1.76			

(1) Background results are abnormally high because of gasoline spillage on carpet floor of vehicle from a fuel can after completion of SHED tests and before running the background tests.

APPENDIX IV

TABLE VIII

SUMMARY OF EVAPORATIVF EMISSION DATA

Make: Buick LeSabre
Year: 75
No.: 8
Displ. cu. in./Litre: 350/5.74

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.90	-	-	-	5.16	-	-	-	6.06	0.06	0.29	
(2) Quantifying #1	0.20	-	1.88(1)	-	1.40(2)	6.52(1)	2.13(1)	1.40(2)	12.13(1)			
(3) Quantifying #2	0.33	-	1.68(1)	-	2.58(2)	3.39	0.49	2.58(2)	8.47(1)			
(4) Quantifying #3	0.21	-	-	-	1.56(2)	4.57	0.0	1.56(2)	6.02			
(5) SHED #2	0.57	-	-	-	7.34	-	-	-	7.98			

(1) Hydrocarbon collecting equipment rate too high. Some HC drawn from canister and air cleaner.

(2) Carburetor leak - carburetor accelerator pump shaft and collar on air horn a very loose fit. No feasible way to trap this leak.

APPENDIX IV

TABLE IX

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Vega
Year: 75
No.: 9
Displ. cu. in./Litre: 140/2.29

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.33	-	-	-	3.49	-	-	-	3.82	0.0	0.57	
(2) Quantifying #1	0.23	-	-	-	0.45	7.17(1)	-	-	7.85(1,2)			
(3) Quantifying #2	0.18	-	-	-	0.50	0.25(2)	-	-	0.93(2)			
(4) Quantifying #3	0.30	-	-	-	0.35	0.16(2)	-	-	0.81(2)			
(5) SHED #2	0.21	-	-	-	5.46	-	-	-	5.67			

(1) Vapor collection rate too high in this case.

(2) Carburetor bowl temperatures are 15 to 20°F (-9.4 to -6.7°C) lower for quantifying runs than for SHED tests. Hood was partially open to accommodate vapor collection equipment.

APPENDIX IV

TABLE X

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Olds "98"
Year: 73
No.: 10
Displ. cu. in./Litre: 455/7.46

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.49	-	-	-	9.11	-	-	-	9.60	0.1	0.31	
(2) Quantifying #1	0.41	-	-	-	1.69(1)	6.92	0.0	1.69(1)	9.02			
(3) Quantifying #2	0.25	-	-	-	1.67(1)	6.78	0.0	1.67(1)	8.70			
(4) SHED #2	0.43	-	-	-	9.98	-	-	-	10.41			

(1) Carburetor leak around accelerator pump shaft. Vapors escaped to the shed because the leak is unaccessible from a quantifying standpoint.

APPENDIX IV

TABLE XI

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Hornet
Year: 74
No.: 11
Displ. cu. in./Litre: 232/3.80

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.20	-	-	-	12.33	-	-	-	12.53	0.0	0.11	
Carburetor to air cleaner gasket replaced. Original one cracked and leaking.												
(2) SHED #2	0.73	-	-	-	10.11	-	-	-	10.84			
(3) Quantifying #1	0.13	-	-	-	6.73(1) 19.10(2)	-		6.73(1)	25.96(2)			
(4) Quantifying #2	0.12	-	-	-	6.52(1) 4.57	-		6.52(1)	11.21			
(5) Quantifying #3	0.18	-	-	-	6.95(1) 4.23	-		6.95(1)	11.36			
(6) SHED #3	0.22	-	-	-	10.54	-	-	-	10.76			

(1) Carburetor leak around accelerator pump shaft. Vapors escaped to shed as leak is unaccessible from a quantifying standpoint.

(2) Flow of hydrocarbon vapors to collector too high.

APPENDIX IV

TABLE XII

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Plymouth Fury III
Year: 73
No.: 12
Displ. cu. in./Litre: 360/5.90

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	4.61	-	-	-	2.79	-	-	-	7.40	0.07	0.66	
(2) Quantifying #1	1.31	-	2.70	-	2.00(1)	0.0	2.41	2.00(1)	8.42			
(3) Quantifying #2	0.86	-	1.45(2)	-	1.70(1)	0.0	1.65(2)	1.70(1)	5.63(2)			
(4) SHED #2	3.50	-	-	-	2.26	-	-	-	5.76(3)			

(1) Carburetor leak around accelerator pump shaft. This loss inaccessible from a quantifying standpoint.

(2) Run No. 3, Quantifying Run #2 is 3.0 grams lower than Quantifying Run No. 1 because the charcoal canister adsorbed 3.0 grams more for the second run. The hydrocarbon level in the canister decreased from Run #1 to Run #2.

(3) The total loss for SHED Test 2 is less than for SHED Test 1 because the working capacity of the canister has increased during this series of tests. This is indicated by lower canister weights for SHED Test 2 than 1.

APPENDIX IV

TABLE XIII

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Dart
Year: 74
No.: 13
Displ. cu. in./Litre: 318/5.21

Test	Diurnal, Grams Loss From SHED	A.C.	Canister	Other	Hot Soak, Grams Loss From SHED	A.C.	Canister	Other	Total Grams	Background Grams Cold	Hot	Remarks
(1) SHED #1	0.16	-	-	-	2.85		-	-	3.01	0.0	0.11	
(2) Quantifying #1	0.13	-	-	-	1.33(1)	1.82	-	1.33(1)	3.28			
(3) Quantifying #2	0.29	-	-	-	1.30(1)	1.57	-	1.30(1)	3.16			
(4) SHED #2	0.18	-	-	-	2.57	-	-	-	2.75			

(1) Carburetor leak - hydrocarbon leak around accelerator pump shaft.

APPENDIX IV

TABLE XIV

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Datsun
Year: 74
No.: 14

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
	SHED	Loss From A.C.	Loss From Canister	Loss From Other	SHED	Loss From A.C.	Loss From Canister	Loss From Other		Cold	Hot	
(1) SHED #1	1.25	-	-	-	2.19	-	-	-	3.44	0.11	0.20	
(2) Quantifying #1	0.53	0.0	-	-	1.57	0.0	-	-	2.10			
(3) Quantifying #2	0.79	0.58	-	-	1.21	0.0	-	-	2.58			
(4) SHED #2	0.90	-	-	-	1.80	-	-	-	2.70			

APPENDIX IV

TABLE XV

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Mazda
Year: 74
No.: 15
Displ. cu. in./Litre: Rotary

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
	SHED	Loss From A.C.	Loss From Canister	Loss From Other	SHED	Loss From A.C.	Loss From Canister	Loss From Other		Cold	Hot	
(1) SHED #1	0.54	-	-	-	11.56	-	-	-	12.10	0.46(1)	1.10(1)	
(2) Quantifying #1	1.36	-	-	-	1.36(2)	7.79(3)	-	1.36(2)	10.51(3)			
(3) Quantifying #2	0.51	-	-	-	1.13(2)	7.60(3)	-	1.13(2)	9.24(3)			
(4) SHED #2	0.86	-	-	-	11.44	-	-	-	12.30			

(1) Evidence of gasoline spillage in the trunk prior to this work. This would account for high background.

(2) Carburetor leaks.

(3) Carburetor bowl temperatures 12-15°F (-11.1 to -9.4°C) lower for quantifying runs than SHED tests because hood was partially open during the hot soak to accommodate the collection equipment.

APPENDIX IV

TABLE XVI

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Comet
Year: 74
No.: 16
Displ. cu. in./Litre: 250/4.10

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.21	-	-	-	20.33	-	-	-	20.54	0.0	0.12	
(2) Quantifying #1	0.16	-	-	-	2.65(1)	11.44	-	2.65(1)	14.25(2)			
(3) Quantifying #2	0.50	-	-	-	2.51(1)	12.79	-	2.51(1)	15.80(2)			
(4) SHED #2	2.12(3)	-	-	-	14.49	-	-	-	17.61(2)			
(5) SHED #3	0.17	-	-	-	14.08	-	-	-	14.25(2)			

(1) Carburetor leak around accelerator pump shaft. Inaccessible from a quantifying standpoint.

(2) Several openings in the air cleaner sealed after SHED Test #2 which accounts for the lower total emissions for these runs than SHED #1.

(3) Tank drain disconnect fitting leaking during diurnal cycle.

APPENDIX IV

TABLE XVII

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Volvo
Year: 74
No.: 17
Displ. cu. in./Litre: 121/1.98

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
	SHED	Loss From A.C.	Loss From Canister	Loss From Gas Cap	SHED	Loss From A.C.	Loss From Canister	Loss From Gas Cap		Cold	Hot	
(1) SHED #1	6.54	-	-	-	4.97	-	-	-	11.51	0.09	0.12	
(2) Quantifying #1	2.89	0.37	0.19	1.34(1)	1.63	1.87	0.0	0.40(1)	8.69(2)			
(3) Quantifying #2	0.77	0.60	0.32	2.33(1)	1.24	3.77	0.30	1.17(1)	10.50(2)			
(4) SHED #2	4.87	-	-	-	3.84	-	-	-	8.31(2)			
(5) SHED #3	4.49	-	-	-	2.62	-	-	-	7.11(2)			

(1) Fuel tank pressure builds up quickly to 1.0+ psig during diurnal cycle and is relieved through the fill cap or any other fittings that may leak temporarily. Fuel tank pressure is 1.0+ psi (6.9+ kPa) at beginning of the hot soak also. Tank temperature increases 9-10°F (-15.0 to -14.4°C) during Federal cycle.

(2) After SHED test #1 (before Quantifying #1 run), the clamps for the flexible portion of the fill pipe were tightened to eliminate a leak. Consequently, subsequent runs are lower in total evaporative emissions.

APPENDIX IV

TABLE XVIII

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Ford
Year: 75
No.: 18
Displ. cu. in./Litre: 460/7.54

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
	SHED	Loss From A.C.	Canister	Other	SHED	Loss From A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	3.70	-	-	-	31.15	-	-	-	34.85(1)	0.0	0.13	
(2) Quantifying #1	0.51	-	2.23	-	14.04(2)	4.90	2.13	14.04(2)	23.81			
(3) Quantifying #2	0.50	-	-	-	15.29(2)	4.38	0.98	15.29(2)	21.15			
(4) SHED #2	0.56	-	-	-	25.75	-	-	-	26.31			
(5) SHED #3	1.07	-	-	-	29.84	-	-	-	30.91			

(1) Losses higher for this run than subsequent runs because of leaks in the air cleaner. These were sealed for quantifying and later SHED tests.

(2) Carburetor leaks - vapors escape around the linkage for the choke plate and bowl vent to the canister.

APPENDIX IV

TABLE XIX

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: VW
Year: 75
No.: 19
Displ. cu. in./Litre: 97/1.6 (Fuel Injected)

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	0.56	-	-	-	1.43	-	-	-	1.99	0.69(1)	0.80(1)	
(2) SHED #2	1.15	-	-	-	1.46	-	-	-	2.61			
(3) SHED #3	0.41	-	-	-	1.14	-	-	-	1.55			

(1) To verify the high background levels for this car, emissions were monitored for 24 hours. For both hot and cold background tests, the rate of hydrocarbon emission had not diminished significantly after 24 hours. Further testing showed that essentially all of the hydrocarbon was being emitted from the outside of the vehicle.

APPENDIX IV

TABLE XX

SUMMARY OF EVAPORATIVE EMISSION DATA

Make: Monarch
Year: 75
No.: 20
Displ. cu. in./Litre: 302/4.95

Test	Diurnal, Grams				Hot Soak, Grams				Total Grams	Background Grams		Remarks
		Loss From				Loss From						
	SHED	A.C.	Canister	Other	SHED	A.C.	Canister	Other		Cold	Hot	
(1) SHED #1	4.41	-	-	-	6.30	-	-	-	10.71	0.0	0.0	
(2) Quantifying #1	0.38	-	2.28	-	3.94(1)	1.86	-	3.94(1)	8.46			
(3) Quantifying #2	0.35	-	1.34	-	3.26(1)	2.48	-	3.26(1)	7.43			
(4) SHED #2	0.91	-	-	-	8.62	-	-	-	9.53			
(5) SHED #3	1.09	-	-	-	6.51	-	-	-	7.60			

(1) Carburetor leak around choke plate linkage.

APPENDIX V

TABLE I

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Ford "LTD"
Year: 75
No.: 1
Displ. cu. in./Litre: 351/5.75

Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a. Purge from inside air cleaner element. b. Barrier in air cleaner at base of snorkel. c. Choke shaft passage sealed.	6.1	
II. Steps a, b, c d. Air horn to body gasket modified to allow more bowl vapors to be stored in air cleaner.	9.6	
III.e. Purge to air cleaner snorkel as well as air cleaner.		

Measurements were made of purge rates for both an air cleaner and a snorkel purge system. Next, a curve of grams removed from canister vs. total purge volume was made. From these data it was estimated that a combination air cleaner-snorkel purge system would remove 13 to 15 grams from the canister during the SHED preconditioning period (4-LA-4s). This is not an adequate system because the combined diurnal and hot soak input to the canister is about 23 grams for the modified vehicle. Consequently, a PCV purge system was installed using a 1974 Vega canister which had been in daily usage up to this time.

IV. PCV purge with Vega canister. The bottom of the canister is capped. An unmodified carburetor body to air horn gasket used along with modifications b and c above.	1.3 1.2	

APPENDIX V

TABLE II

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Pontiac
Year: 75
No.: 2
Displ. cu. in./Litre: 400/6.56

Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a. Vented carb. bowl to canister. b. Sealed leak around accel. pump shaft.	10.5 (diurnal)	
II. Steps a and b c. Restriction in line from bowl to canister.	3.4	Canister dried up before run.
III. Steps a, b, c d. Underhood ventilated with a fan.	1.6	Fan lowers carb. bowl temp. about 30°F (-1.1°C).
e. Bottom on canister	2.5	
	1.7	

APPENDIX V

TABLE III

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Chrysler
Year: 75
No.: 3
Displ. cu. in./Litre: 440/7.21

Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a. Underhood ventilated with fan.	10.8 (diurnal)	Fan only lowered c.b. temp. 5-15°F. Not blowing directly at carburetor.
b. Carb. bowl volume lowered	12.0 (diurnal)	
c. Barrier installed at base of a.c. snorkel.		
d. Accel. pump shaft leak sealed.		
II. At this point it was determined that one canister would not have sufficient capacity to handle total evap. emissions. With a single canister, preconditioning removes 36-40 grams from a fully charged canister. The last LA-4 removes only 1 to 2 grams. Combined diurnal and hot soak losses are 50 grams. A Chrysler canister from a 1975 vehicle in daily usage was used as a second canister.		
e. Two canisters installed in parallel.	2.1(1)	
f. Second carb. bowl vented directly to canisters.	2.5(1)	
g. Bottom installed on canisters.		
Steps b, c, and d above also used		

(1) Exhaust emission data were very erratic. Inasmuch as this vehicle had to be returned to the rental agency, a second car will be obtained for further tests.

APPENDIX V

TABLE IV

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Chrysler
Year 75
No.: 21
Displ. cu. in./Litre: 440/7.21

Modifications	Evap. Emissions, g/SHED Test	Remarks
I Original ECS	13.4	Diurnal - 6.3 g, H.S. - 7.1 g
Original ECS	14.6	Diurnal - 4.4 g, H.S. - 10.2 g
II Modified ECS:		
(a) Two canisters in parallel used		
(b) Second carb. bowl vented directly to canister		
(c) Bottom on each canister	1.9	
(d) Barrier at base of snorkel	2.0	
(e) Accel. pump shaft leak sealed		

APPENDIX V

TABLE V

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Hornet
Year: 74
No.: 11
Displ. cu. in./Litre: 232/3.80

Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a. Carb. bowl vented to the canister. b. Accel. pump shaft leak sealed.	3.9	
II. Steps a and b above - restriction in line from carb. bowl to canister. c. Barrier installed in air cleaner at base of snorkel.	3.1	
III. Steps a, b, c above d. Bottom of canister closed.	2.5	
IV. ECS modified to a PCV purge system using a 1974 Vega canister. Steps a, b, c, and d above also continued.	1.2 1.3	

APPENDIX V

TABLE VI

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Mazda
Year: 74
No.: 15
Displ. Cu In./Litre: 80/1.31 (Rotary)

Step	Modifications	Evap. Emissions g/SHED Test	Remarks
I	Both carburetor bowls vented to a 3 tube canister (Chrysler). Purge is through existing purge line to PCV. Original ECS used for diurnal.	4.8, 3.8	Hydrocarbon vapors escaping from snorkel.
II	Next, the modifications indicated below were tested. In each case, the hydrocarbon level from the SHED test exceeded 2.0 grams. 1. Canister moved outside of engine compartment to a cooler environment. 2. Canister dried up on vacuum pump prior to diurnal and hot soak. 3. Air cleaner canister closed off and 3 tube canister used for both diurnal and hot soak. At this point, additional source determination tests indicated hydrocarbon vapors emanating from carburetor throat due to fuel drippage. To alleviate pressure in the carburetor bowl, a fan installed to lower bowl temperature by ventilating the underhood engine compartment.		
III	Modifications for Step I. Underhood fan to ventilate underhood. At this point, the 3 tube canister was changed to a 4 tube Vega with a purge control valve. (Used canister from 1974 Vega.) High diurnal losses in above runs due to tank vapors passing into engine crankcase, then through PCV purge line into 3 tube canister. Vapors then moved out of the canister into the carburetor bowl and air cleaner through the vent line from the bowl to the canister. The purge control valve prevents this migration of vapors into the carburetor bowl and air cleaner.	2.8	
IV	Modifications for Step I with exception of replacing 3 tube canister with a 4 tube unit. Fan to ventilate underhood.	1.8, 1.3	

APPENDIX V

TABLE VII

SUMMARY OF EVAPORATIVE EMISSIONS FROM MODIFIED VEHICLES

Make: Volvo
Year: 74
No.: 17
Displ. cu. in./Litre: 121/1.98

Modifications	Evap. Emissions, g/SHED Test	Remarks
I.a. Equalizing valve modified so as to relieve fuel tank pressure at 0.5 psig.	0.4	CO and HC exhaust levels higher with modified ECS.
b. Baffle installed between fuel tank and muffler.		
c. American Motors canister used.	1.7	

APPENDIX VI

ESTIMATED COSTS FOR VEHICLE MODIFICATIONS

Car No.	Make	Modification	Cost $
1	LTD	Canister replacement (1)	$ 1.00
		Seal-carb. leak	0.30
		Barrier-snorkel base	0.20
		Air cleaner sealing	0.30
		Canister bottom cap	0.20
		Total	$ 2.00
2	Pontiac	Bowl vent to canister	$ 0.50
		Seal-carb. leak	0.30
		Canister bottom cap	0.20
		Air cleaner sealing	0.30
		Fan	17.00(1.00) (2)
		Total	$18.30(2.30) (2)
21	Chrysler	Canister replacement (3)	$ 4.00
		Canister bottom caps	0.40
		Bowl vent to canister	0.50
		Barrier-snorkel base	0.20
		Seal-carb. leak	0.30
		Air cleaner sealing	0.30
		Total	$ 5.70
11	Hornet	Canister replacement (4)	$ 1.00
		Seal-carb. leak	0.30
		Bowl vent to canister	0.50
		Air cleaner sealing	0.30
		Canister bottom cap	0.20
		Barrier-snorkel base	0.20
		Total	$ 2.50
15	Mazda	Bowl vent to canister (two)	$ 1.00
		Canister	7.00
		Fan	17.00
		Canister bottom cap	0.20
		Total	$25.20
17	Volvo	Canister Replacement(5)	$ 1.00
		Baffle between tank and muffler	1.00
		Total	$ 2.00

(1) Price difference between 3 tube and 4 tube canister.
(2) Numbers in parenthesis are costs associated with the Vega canister system.
(3) Price difference between original 3 tube canister and 3 tube with 50% larger capacity.
(4) Price difference between 2 tube and 4 tube canister.
(5) Price difference between 1 tube and 2 tube canister.

APPENDIX VII

HIGH RVP FUEL IN SHED TEST

Fuel RVP: 71.7 kPa (10.4 psi)

I SHED Results

Car No.	Make	SHED Test, Grams		
		Total	Diurnal	Hot Soak
1	LTD	6.2	2.6	3.6
		5.2	2.1	3.1
2	Pontiac	4.4	3.2	1.2
		2.1	0.9	1.2
		2.3	1.3	1.0

II Exhaust Emission Data

Car No.	Make	Grams/Mile(1)		
		CO	HC	NO_x
1	LTD	5.19	0.46	1.45
2	Pontiac	4.69	0.76	1.16

(1) Average of two tests.

APPENDIX VIII

HIGH TEMPERATURE DIURNAL SHED TEST DATA

Diurnal Cycle: 15.6 - 35°C (60-95°F)

I SHED Results

Car No.	Make	SHED Test, Grams		
		Total	Diurnal	Hot Soak
1	LTD	4.8	1.9	2.9
		4.0	2.3	1.7
2	Pontiac	4.2	3.2	1.0
		3.7	2.4	1.3

II Exhaust Emission Data

Car No.	Make	Grams/Mile(1)		
		CO	HC	NO_x
1	LTD	5.28	0.44	1.95
2	Pontiac	3.83	0.88	1.19

(1) Average of two tests.